NINETEENTH REPORT OF THE

ONTARIO BUREAU OF MINES: PART II.

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Section
No 817

Fig. 1. The Little Silver Vein, southwest corner of location R. L. 404, on the Nipissing property. The cliff is about 70 feet in height and is composed of almost horizontally lying rocks of the Cobalt series. At the bottom are about 15 or 20 feet of well banded slate-like greywacké. This is followed by about the same thickness of feldspathic quartzite, overlying which, at the top of the cliff, is coarse conglomerate. The greatest thickness of the vein, as originally exposed, was about 8 inches. The strike is east and west, and the dip, as the photograph shows, is almost vertical. Ore to the value of about $300,000 was extracted from this vein.

REPORT OF
THE BUREAU OF MINES

VOL. XIX., PART II.

The Cobalt-Nickel Arsenides and Silver Deposits of Temiskaming

(Cobalt and Adjacent Areas)

BY

WILLET G. MILLER, Provincial Geologist

(FOURTH EDITION)

With an Appendix on—I. The Paleozoic Rocks of Lake Temiskaming
II. Profile from Toronto to the Hudson Bay Slope
III. "Early History of the Cobalt Industry in Saxony," translated by Geo. R. Mickle
IV. Mining and Concentrating Methods at Cobalt

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1913

"The detection of a small portion of cobalt in association with these metals upon the shores of Lake Huron, should lead us to look for deposits of this rare and valuable material."
—T. Sterry Hunt, in Report of Geological Survey of Canada for 1848-9.

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MAPS AND SECTIONS

Colored geological map of cobalt-nickel-arsenic-silver area, near lake Temiskaming, scale 1 mile to 1 inch.

Uncolored index map of part of the Cobalt area, showing veins and position of lines of sections, scale 800 feet to 1 inch.

Map of the Gowganda area, scale 1 mile to 1 inch.

Uncolored geological sketch map of the township of Leonard.

Geologically colored cross sections, horizontal scale, 800 feet to 1 inch.

Maps and sections in the text—Figs. 5, 6, 7, 21, 28, 30, 31, 32, 36, 51, 57, 62, 63, 70, 95, 96, 106, 108.

PREFACE TO THE FOURTH EDITION

The third edition of this report, published in May, 1908, has been out of print for some time. Owing to the rapid development of the mineral industry in the newer districts of the Province, necessitating the preparation of geological maps and reports on several virgin areas, the publication of the fourth edition has been delayed. Moreover, it was felt that in so far as the economic geology of the Cobalt area is concerned, there is little to add to the descriptions that were given in former editions of the report. Some features have been treated more fully in this edition, underground work in the mines having furnished many details concerning the structural relations and the character of the veins. Advantage has been taken of this information to prepare several cross-sections and other illustrations, which it is hoped will add interest to the report.

As regards its production, the area is unique. It is not only the world's greatest producer of silver, but it absolutely controls the market for cobalt, has a large output of arsenic, and is among the three or four areas that have the largest output of nickel.

Owing to its accessibility, its proximity to the great centres of populations of eastern North America, the large number of producing properties, the huge capitalization of the companies, the comparative uniqueness of its ore bodies, and the difference of the geology from that of most precious metal mining areas, it is safe to say that Cobalt has been visited and studied by more mining engineers and geologists than any other mineral area in the same length of time.

In so far as the geology is concerned, Cobalt has served as a key area for a large district. Previous to the beginning of our field work in 1904, the Keewatin and Huronian in this part of Ontario and the adjacent part of Quebec were thought to belong to one series. The Keewatin had been mapped as Huronian. Our first report showed that the two series are different in origin, and that they are separated by a great unconformity. Work that has since been done by the Geological Survey of Canada on the Quebec side of lake Temiskaming and farther north and west, and that done by our own parties in the Elk Lake, Gowganda, Porcupine and other areas has shown that the geology of the whole region is similar to that of Cobalt. Any person having a good knowledge of the geology of the Cobalt area has little difficulty in mapping other areas in this region.

Maps

The colored geological map of Cobalt, on a scale of one mile to the inch, which has gone through three editions, besides being reprinted two or three times, was revised and enlarged, under the direction of Mr. James Bartlett, and published in 1910. It accompanies this edition of the report. The enlarged map covers all of the Gillies timber limit, the South Lorrain area and part of the township of Casey and adjacent tracts at the head of lake Temiskaming. In this territory, Casey and South Lorrain have been found to contain the only producers of silver outside of the Cobalt area proper, which may be considered to include the townships of Coleman, Bucke, Lorrain, and the Gillies limit. The routes of the hydraulic and the hydro-electric power lines and other features have been added to this edition of the map.

There also accompanies this report a revised edition of the uncolored map, on a scale of 800 feet to the inch, of the area in the immediate vicinity of Cobalt. It shows the names of the properties, the productive veins, the position of the lines of sections and so forth.

A colored geological map of the Gowganda area, on a scale of one mile to one inch, has been published.

The Bureau still has a supply of the large scale, geologically colored map for distribution. This map was published with the third edition of the report It is on a scale of 400 feet to the inch, with contour intervals of 10 feet.

The geological map of the Elk Lake and Montreal River areas, scale one mile to one inch, that accompanied the third edition is out of print.

Sections

Underground work in the mines has made it possible to prepare more complete vertical sections illustrative of the structural relations of the three great groups of rocks—the Keewatin, the Cobalt series and the Nipissing diabase. While these sections furnish more detailed information concerning the structural relations of the rocks, they do not introduce any new principles. During our field work, in 1904, the discovery was made that the diabase is in the form of a sill, which intrudes both the Keewatin and the Cobalt series, and that the rocks overlying the diabase, the upper wall, have been removed over the greater part of the productive area by erosive agencies. Most of the veins which have been, or are being, worked at Cobalt lie below the sill, or rather below the eroded parts of it. Doubtless the veins or parts of veins enclosed in the now, for the most part, eroded upper wall of the sill were more extensive than those lying below it. The geological sections accompanying this report show the relation of the sill to the other rocks and the position of the veins.

Title of Report

The title "Cobalt-Nickel Arsenides and Silver of Temiskaming" has been retained for this edition in preference to the name Cobalt, which is commonly applied to the area. The title is essentially that given to the first paper on the mineral deposits written at the end of 1903, and published in the *Engineering and Mining Journal*, of New York, Dec. 10th, 1903. It has been thought best to retain the same title for the various editions in order to prevent confusion in the literature.

Markets and Refining

During the first two or three years, practically all of the ore was shipped out of the country in the crude state. Most of the ore is now refined in Ontario, a considerable part of the silver being shipped in the refined state from Cobalt. Plants in other parts of the Province not only produce refined silver from the Cobalt ores, but they also have a large output of white arsenic, and are producers of cobalt and nickel oxides.

Mines, Concentration and Power Plants

Since the underground work in mines and the plants of the Cobalt silver areas are described in Part I. of the annual reports of the Bureau of Mines, and in Mr. A. A. Cole's annual reports to the Temiskaming and Northern Ontario Railway Commission, it is not considered necessary to repeat the descriptions in this report. However, in Appendix IV., a summarized description is given of mining and concentrating methods employed in the silver areas. This description is by Mr. E. T. Corkill.

Production and Dividends

Outside of the Cobalt area proper, in the township of Coleman and the Gillies timber limit, the chief producers of silver are the Casey Cobalt, the Wettlaufer mine, in South Lorrain, and the Millerett, the Mann, and Miller Lake-O'Brien, in the Gowganda area. Small shipments have been made from the Elk Lake area, from the vicinity of Maple mountain, in the township of Whitson, and, at an earlier date, from a part of the township of Bucke, in the vicinity of lake Temiskaming. The index maps, pages 47 and 117, show the situation of the various areas mentioned.

For the whole period, up to the end of 1912, since the mines were opened, Cobalt has produced 155,815,839 ounces of silver, the value being $81,731,115; the quantity of

cobalt, nickel and arsenic is known only approximately. Statistics are given on a following page. Up to the end of the year, the total dividends distributed amounted to $39,834,740, not including the profits made by two or three mines, either privately owned or close corporations. The dividends have been equal to approximately fifty per cent. of the output.

Profits from Railway Building

By the time this report is through the press, the dividends distributed by Cobalt mines will amount to about $45,000,000. The construction of the Temiskaming and Northern Ontario railway, together with equipment, has cost the Province approximately $18,500,000. As the building of the railway led to the discovery of the mineral deposits of Cobalt, it will be agreed that the railway was a profitable undertaking for the people. In addition to the sum distributed directly as profits, the Cobalt area has produced approximately another $45,000,000 or more, which has been expended in the Province for labor, food supplies, machinery and other materials. Moreover, the people, as represented by the government, have received four or five million dollars in cash from Cobalt through the sale of lands, from royalties, fees and otherwise, and had it not been for the mines, the railway would have been run at a heavy loss.

Cobalt has not only paid for the railway twice over, but the people have in the railway, now that it is connected with the National Transcontinental, a valuable property which enhances the value of the agricultural lands and timber limits tributary to it, and offers an incentive to the opening of mineral areas such as Porcupine.

It may be added that Cobalt has not only brought great profit to the Province of Ontario, but it has established faith in the mineral resources of the great pre-Cambrian regions, which occupy fully one-half of the surface of Canada. Lying on the southern point of these regions, it offers encouragement to the prospecting of the vast, and little known, territories of the hinterland.

It may not be out of place to refer to the preface to the second edition of this report concerning the benefits and injuries derived from the discovery of the Cobalt deposits. This introduction was written in February, 1906. The feared "mining on paper" began with the "boom" in August of the same year. While the public undoubtedly lost much money in foolish gambling in stocks, almost innumerable worthless properties being put on the market and many of the best mines being over-capitalized, the mineral industry is not to blame. Mining is as safe as any other industry, if ordinary precautions are taken. No part of the world, possessing virgin mineral areas, is as well situated for the securing of capital for mining enterprises as is Ontario and adjacent parts of Canada. Eastern North America contains a population of over fifty million people, with great wealth and with the characteristic of being willing "to take a chance." Our mineral areas can be said to be at the back door of this population. It is not surprising that almost every mining boom is carried to extremes.

Acknowledgments

The author desires to express his most sincere thanks to the prospectors, mine operators and other men, who are, or have been, connected with the development of the Cobalt area, for the kindness which he has received at their hands, and for the assistance in the study of the area, which they have always extended to him. The study has been interesting and the association with the men of the area will always remain a cherished memory.

It is with much pleasure that the author acknowledges the valuable assistance that has been so cordially given to him by members of the staff of the Bureau of Mines. During the last four or five years, since the publication of the third edition of the report, owing to the widespread mining activities in Ontario, a province that now has an area nearly three and a half times as great as the British Isles and about twice that of France or Germany, it has been possible to give attention to Cobalt only at irregular intervals. Thanks are especially due to Mr. Cyril W. Knight, Assistant Pro-

vincial Geologist, for his hearty co-operation, and the kindly interest he has taken in the work. Mr. E. T. Corkill, Chief Inspector of Mines, has furnished much useful information. The work of Mr. A. G. Burrows on the outlying cobalt-silver areas has been of much service. Mr W. R. Rogers has rendered valuable assistance in the preparation of the report, as have several assistants who have been associated with the staff during shorter periods. Most of the chemical work made use of in the report has been performed by Messrs. A. G. Burrows, N. L. Turner and W. K. McNeill.

Toronto, May, 1913. W. G. M.

Fig. 2.—Cobalt Station, June, 1905.

Fig. 3.—View of part of Cobalt, showing railway station and hotel, December, 1905.

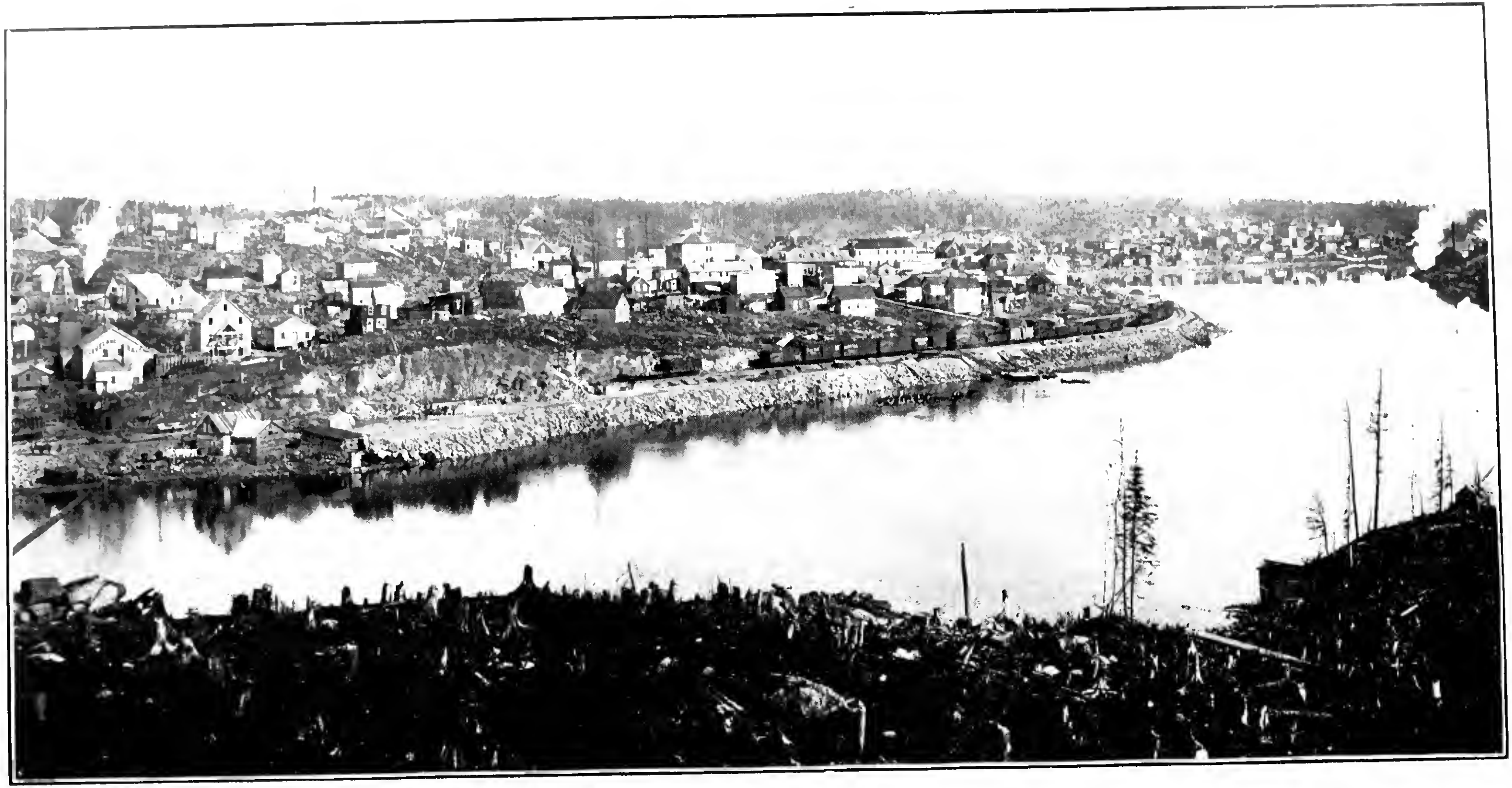

Fig. 4.—Cobalt in 1907, with Cobalt Lake in the foreground.

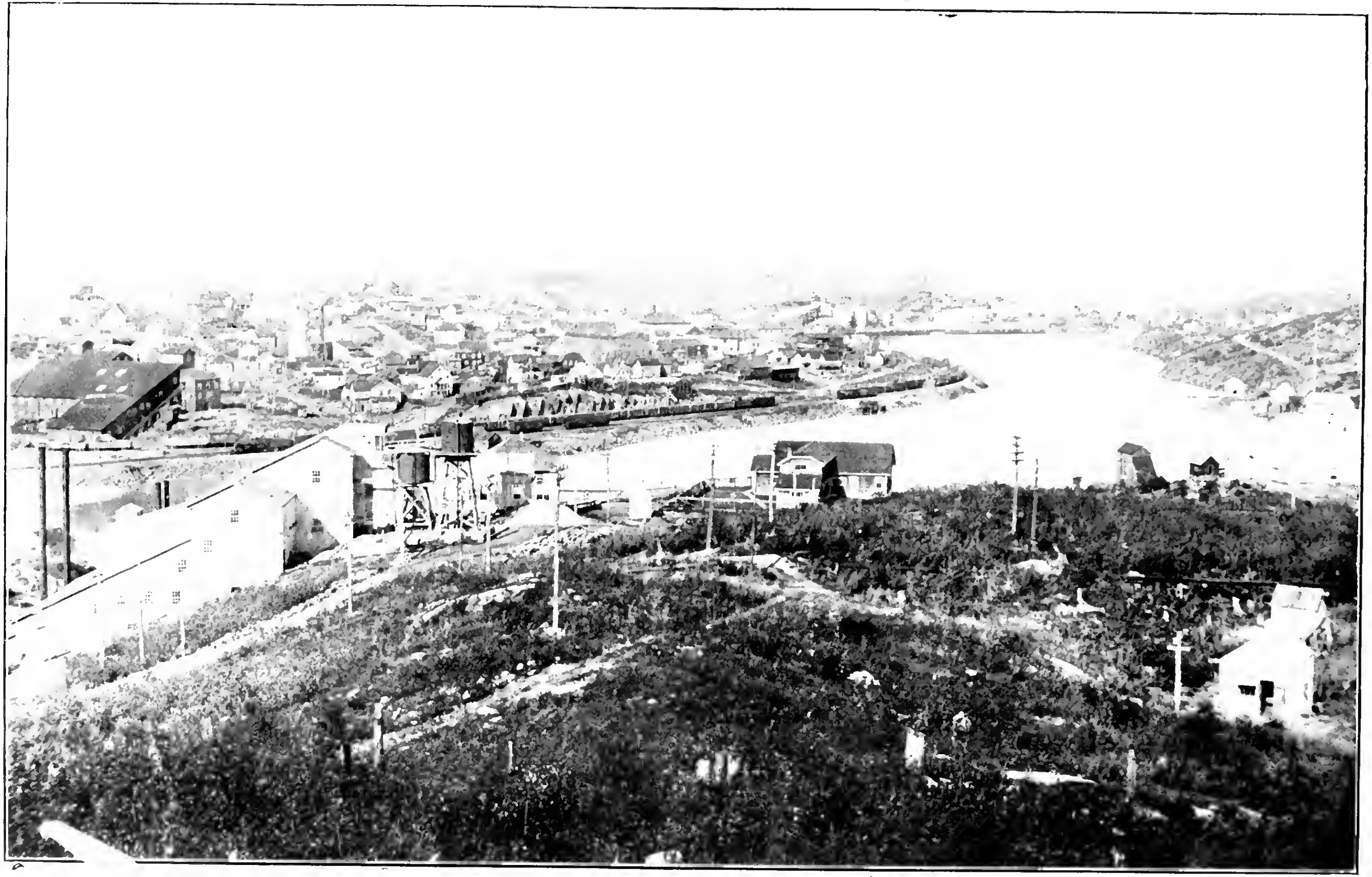

Fig. 4a.—General view of Cobalt Lake and Town, September, 1911.

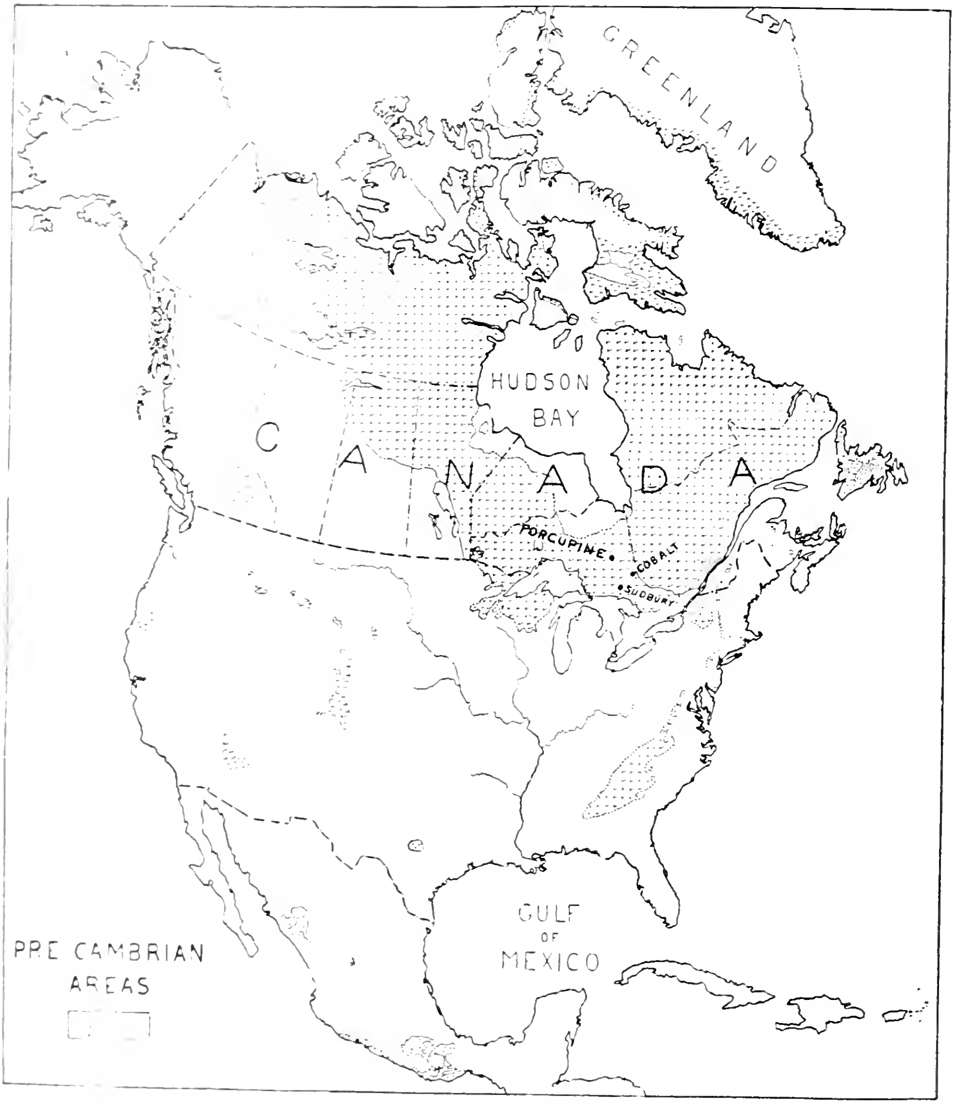

Fig. 5. Pre-Cambrian of North America, showing situation of Cobalt.

Cobalt-Nickel Arsenides and Silver
(Cobalt and Adjacent Areas)

By WILLET G. MILLER

CHAPTER I

Introduction

The protaxis, or that rugged, rocky, pre-Cambrian region which stretches away from the St. Lawrence river, expanding to the northwestward, and occupying a large part of northern Ontario, has produced, and is constantly producing, a group of what may be called unique, or at least comparatively rare, economic minerals. Probably as great a variety of minerals is produced here in proportion to the number of inhabitants as is derived from any other country. Among the economic deposits are:

The nickel-copper mines of Sudbury, which is the greatest nickel producing locality of the world, with the by-products, platinum and palladium;

The gold deposits of Porcupine and other northern areas;

The corundum deposits of north Hastings, south Renfrew and other areas in eastern Ontario, which now supply by far the greater part of the corundum consumed in the world;

The unsurpassed feldspar and mica deposits of Frontenac and adjoining counties and the apatite, graphite, pyrite, talc, gold, copper, zinc, lead, fluorite and barite of the same district;

The iron ranges, which extend over a great territory in northern and northwestern Ontario, but which, up to the present, have not been developed to a great extent;

In addition to these, it may be said that a few years ago north Hastings possessed the only arsenic plant in North America. More recently the auriferous-arsenic ores of Temagami were made known, and lastly discovery was made of the series of Cobalt-Nickel Arsenides and Silver, which is unique, so far as known, on this continent, and is paralleled by deposits only in Saxony and adjacent regions of continental Europe.

The southeastern part of this region is also noted for certain minerals which can scarcely be said to be of economic value, but are of great scientific interest. The largest and finest crystals of the mineral zircon in the museums of the world come from eastern Ontario, as do also sphenes, pyroxenes, scapolites and other crystals. Sodalite, marble and other decorative materials are also found here.

The situation of Cobalt in the protaxis, or pre-Cambrian regions, will be seen from the accompanying sketch map of North America (Fig. 5). A profile from Toronto, on Lake Ontario, to the James Bay slope shows that the protaxis is not such a distinct "height of land" as it is usually described to be (Appendix II). It is only since the completion of the Temiskaming and Northern Ontario Railway that such a profile could be prepared.

Situation and Discovery

A brief description of the character and modes of occurrence of the Cobalt-Silver ores of the area is given, as marginal notes, on the colored geological map which accompanies this report. For practical purposes, it is not necessary to add much to these. In the report which was published in the Thirteenth annual volume of the Bureau of Mines an account of the discovery and location of the ore bodies was given. It may be well to repeat briefly some of this information.

These ore bodies, which carry values in silver, cobalt, nickel and arsenic, were discovered during the building of the Temiskaming and Northern Ontario Railway. In fact, it may be said that the railway discovered the deposits, as it runs almost over the top of one of the most important veins.[1] The finding of such rich ore within so short a distance of the shore of lake Temiskaming, a stretch of water which has been a well-travelled route to the north by white men for 200 years or more, and the deposits being only about four miles from the town of Haileybury, show the possibilities there are for the discovery of important mineral-bearing areas in the vast hinterland of Ontario, much of which is little known.[2] The first of these ore bodies to be worked lies within half a mile of what is now known as Cobalt station, distant by rail 103 miles from North Bay junction on the transcontinental line of the Canadian Pacific, and 330 miles almost north of the city of Toronto.[3] It may also be added that one of the oldest known ore bodies in North America, the argentiferous galena on the east side of lake Temiskaming, is distant only 8 or 9 miles from Cobalt station. This galena deposit was apparently discovered by voyageurs over 150 years ago. A map of the lake published in 1744 has a bay marked on it with the name "Ance à la Mine," thus showing that the deposit was known at least at that date, and probably much earlier, owing to the

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1 It may be added that the Canadian Pacific railway virtually discovered the Sudbury nickel deposits, 90 miles to the southwest of Cobalt. It can thus be said that each of the two railways in this part of Ontario brought to light an important and little dreamed of mineral field.

A FORECAST.

It may be interesting to note that the writer made the following comment on the mineral possibilities of the district in a report over two years before the discovery of the cobalt deposit:—

"It will be seen from what has been stated on preceding pages that the district examined contains as great a variety of rocks as probably any part of the Province of equal area. . . .

"Although few discoveries of economic minerals have been made in this territory, it may reasonably be expected, judging from the character and the variety of the rocks, that deposits of value will be found when the district is more carefully prospected, as it will be in a short time, owing to the rapid settlement which is now taking place. . . . It would seem that at least some of the conditions of the Sudbury district are repeated in this more eastern field." (Report on "Lake Temiskaming to the Height of Land" in the Eleventh Report of the Bureau of Mines, page 229.) This report gives an account of the rocks and of the canoe routes from Lake Temiskaming northward to the Height of Land.

2 At an early date French fur traders penetrated the district surrounding Lake Temiskaming and the Upper Ottawa. Delisle's map of 1703 shows that the French had a post on the river Abitibi, to the northeast of the head of Lake Temiskaming. Champlain's map, 1632, has a rude outline of the Ottawa river above its junction with the Mattawa.

3. The name Cobalt appears to come from the German Kobold, meaning goblin or house spirit. The metal was so called by the miners because its ore, being arsenious, was poisonous and difficult to treat. The writer felt, however, when he suggested the name for the town, that in this age such a name would not be considered unlucky.

THE CHRISTENING OF THE TOWN OF COBALT.

Fearing that the name "Long Lake," which had been in use for the construction camp, would be retained for the station which it had been decided to place at this point on the railway, the writer endeavored to select a name which would be in keeping with the locality. As an experiment he put up a post, in the first week of June, 1904, on the railway near the lake, and wrote on a piece of board attached to the post, "Cobalt Station, T. & N. O. Ry." The name took at once, as was seen when the writer visited Haileybury a few days afterwards. The workmen and others from Long Lake who had registered at the hotel meantime had all given their addresses as "Cobalt."

On the 7th of June, 1904, the writer wrote to Mr. T. W. Gibson, Director of the Bureau of mines, concerning the name of the station.

EXTRACT FROM LETTER FROM W. G. MILLER TO T. W. GIBSON.

I wish you would suggest to the Commissioners of the T. & N. O. Ry., or whoever has the naming of the stations along the line, that they call this station at Long Lake, Cobalt Station." "There will be a post office here in time—there are enough people here for one already and there is now a Long Lake post office in Frontenac County. The name 'Cobalt' would be unique. It would serve to advertise the place, and miners and others would not get mixed in their stopping off place, as they might if the station is simply called 'Long Lake.'"

On June 11th, Mr. Gibson wrote to the Secretary of the Railway Commission, Mr. P. E. Ryan, concerning the calling of the station "Cobalt." Two days afterwards, on June 13th, Mr. Ryan wrote as follows to Mr. Gibson:

I beg to acknowledge receipt of your favor of the 11th inst., suggesting that the station which will probably be established at Long Lake, south of the Township of Bucke, be called 'Cobalt.' The suggestion which you make strikes me as being a good one, and I shall have pleasure in bringing your letter before the Commission at the proper time."

Shortly after the receipt of Mr. Ryan's letter the Commissioners met and accepted the name "Cobalt" for the station, which is now known throughout the world.

fact that the ore outcrops at the water's edge and is of such a character as to attract attention (Figs. 6, 55).

Some of these veins in the vicinity of Cobalt station were apparently noticed by the men employed in railway construction in the spring of 1903, but, there being no miners or prospectors among them, little interest was aroused and nothing was heard of the discovery by prospectors till October of the same year. At that time Mr. T. W. Gibson, Director of the Bureau of Mines, then in that part of the Province, was given a sample of niccolite which the donor thought was copper ore, the color of this mineral being like that of copper as the German name, kupfer-nickel, indicates. Mr. Gibson, however, recognized the value of the sample and forwarded it to the writer, who was then in the eastern part of the Province, and asked him to make a report on the occurrence as soon as possible. The writer, although he knew the specimen represented high class ore, hardly expected to find ores of the character and in the quantity which he saw on his arrival.[4] This mineral, niccolite, had been found some years before in association with the lower grade nickel ores of some of the Sudbury deposits, but no great quantity of it has up to the present been discovered in the Sudbury field, the town of which name lies about 90 miles southwest of Cobalt station. It may, however, be stated that the Sudbury ore deposits are quite different in character and in origin from those at Cobalt, although the metal nickel is an economic constituent in each.

The Sudbury deposits have received a great deal of attention from geologists during the last fifteen years or more, and two important reports have been published on them. These are by Dr. A. E. Barlow, for the Geological Survey, and by Professor A. P. Coleman for this Bureau.[5] Nearly all the writers agree that the ores are essentially of igneous origin—that is, that the nickeliferous magnetic pyrites or pyrrhotite and copper pyrites have separated from a molten mass of rock.

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4 At the time of the writer's arrival in the district, in November, 1903, 4 veins, all of which were very rich, had been found. Three of these were within sight of the railway, and the fourth was a short distance to the southeast. The blackened, tarnished silver had up to that time attracted little or no attention, although it occurred in profusion in two or three of the weathered outcrops At the present time about 115 veins, that may be considered important producers, have been found. Although the writer's first report of his examination of this cobalt-silver area was published in November, 1903, the public evinced little interest in the field until about eighteen months afterwards, when reports were made of shipments from various properties. The lack of interest was apparently due to the fact that the evil effects of the mining boom of a few years previous had not died out, and the public were more or less sceptical of reports on mining, no matter from what source they might emanate. By June, 1905, interest was aroused in the district throughout North America, and the rush to Cobalt has been greater than has been seen before in the mining fields of Ontario.

The following extracts from letters written in the autumn of 1903, by Mr. T. W. Gibson, Director of the Bureau of Mines, may now have some historical interest.

(Extract from letter from T. W. Gibson to W. G. Miller, then inspecting mineral propertes in the vicinity of Perth, Ontario.)

Bureau of Mines, Toronto, Oct. 26th, 1903.

"I am enclosing herewith a fragment of a larger sample of what I take to be kupernickel, found along the line of the Temiskaming & Northern Ontario Railroad. The locality of the deposit is in the unsurveyed territory immediately south of the township of Bucke. I have not learned anything as to the extent of the discovery, but if the deposit is of any considerable size it will be a valuable one on account of the high percentage of nickel which this mineral contains. I think it will be almost worth your while to pay a visit to the locality of the discovery before navigation closes. I am under the impression that the find was made while making the cutting for the railway. Mr. Ferland, of Haileybury, showed me a sample of the mineral when I was there, but he did not appear to recognize it or know its value, deeming it a compound of copper. It would be rather remarkable should our nickel deposits turn out to have a wider range than has hitherto been supposed, and especially if the new outcrop should be a large one, containing ore of so high a grade."

(Extract from letter from T. W. Gibson to W. G. Miller, addressed in Haileybury.)

Bureau of Mines, Toronto, Nov. 13th, 1903.

"I duly received your letters of the 6th and 9th inst., respecting the progress you are making in looking up the really wonderful finds which appear to have been made in the locality where you are. I hope you will be able to procure a first-class set of samples for the Bureau from all the discoveries, and am waiting with some degree of anxiety your report on the western deposit, namely, the one at Loon Lake."

On November 16th, 1903, the Toronto "Globe" had a half-column article, based on letters of W. G. Miller to the Bureau of Mines. The following sentences indicate the tenor of the article: "Rich discoveries along government railway. . . . Exceeding rich in nickel. . . . Silver, cobalt and arsenic also found. . . One specimen of silver obtained by Mr. Miller was about the size of his hand, and half an inch thick.

On November 20th, another half-column article, an interview with W. G. Miller, appeared, in which are these sentences, "Temiskaming minerals. . . Prof. Miller returned with samples. Says there is no doubt as to the importance of the find. . . . One large piece of silver weighs about ten pounds."

Interviews of this date also appeared in several other Toronto newspapers.

5 Geol. Sur. Can. Part H, Vol. XIV, 1904. Ont. Bur. Mines, Part III, Vol. XIV, 1905. A report on Sudbury, by Dr. Coleman is to be published by the Mines Branch, Ottawa, in 1913.

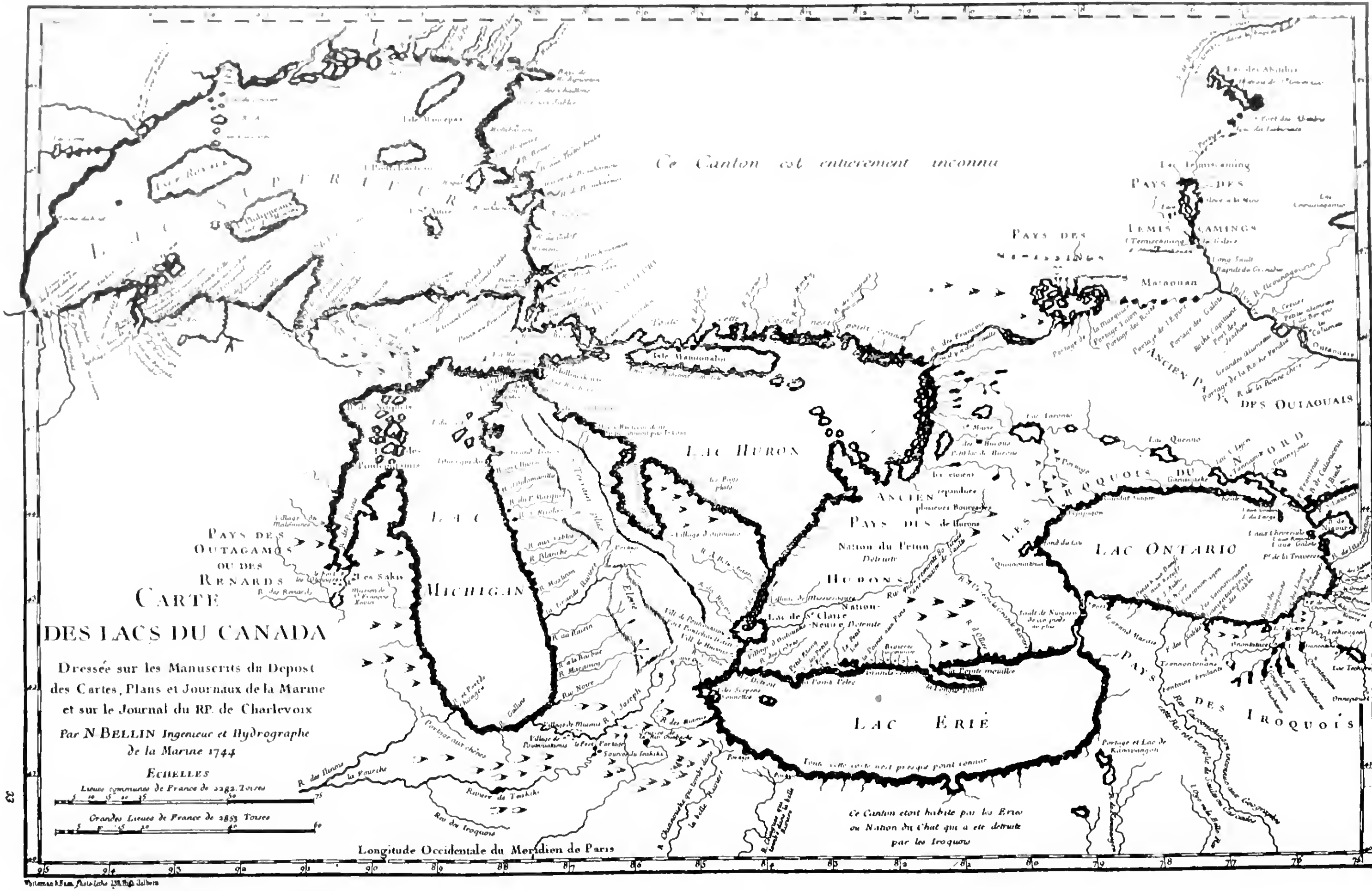


Fig. 6. Map published in 1744 showing that the argentiferous galena deposit on the east side of Lake Temiskaming (Ance à la Mine) was known at that date.

Character and Origin of Cobalt Veins

The deposits at Cobalt, on the other hand, occupy narrow, practically vertical fissures and joint-like cracks that cut through a series of slightly inclined metamorphosed fragmental rocks of pre-Cambrian age, known as the Cobalt series (Fig. 1). A few productive veins of similar form have been found in the adjacent intrusive diabase, known as the Nipissing diabase, and in the Keewatin, the oldest or basement series of the district, consisting typically of basic volcanic rocks. The two most productive veins in the Keewatin have been vein 26 on the Nipissing and that of the Temiskaming. The former vein lies near the edge of Peterson lake and close to the western edge of the diabase sill. Before erosion of the sill took place vein 26 lay beneath the sill or in its foot-wall. The Temiskaming vein, on the other hand, lies in the upper or hanging wall of the sill. There are examples of veins which run from the conglomerate and other fragmental rocks of the Cobalt series into the underlying Keewatin, and there are veins, *e.g.*, Nova Scotia and Temiskaming veins, which run

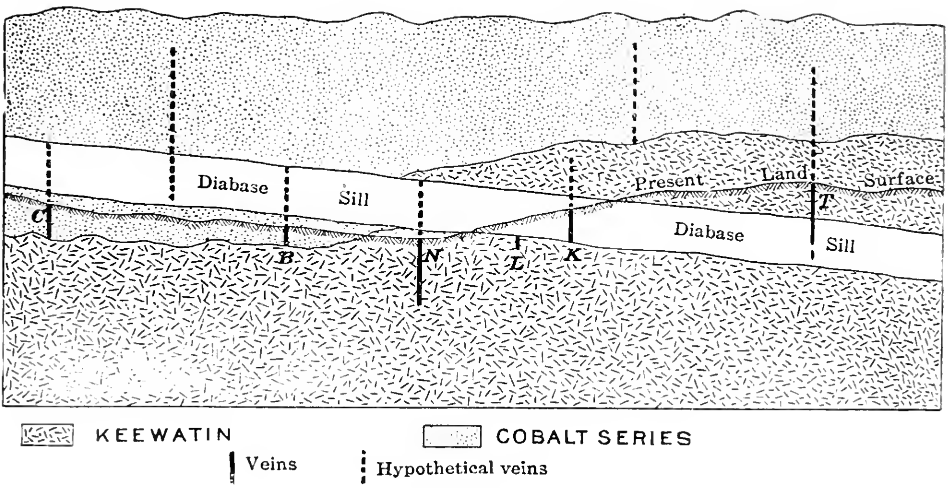


Fig. 7.

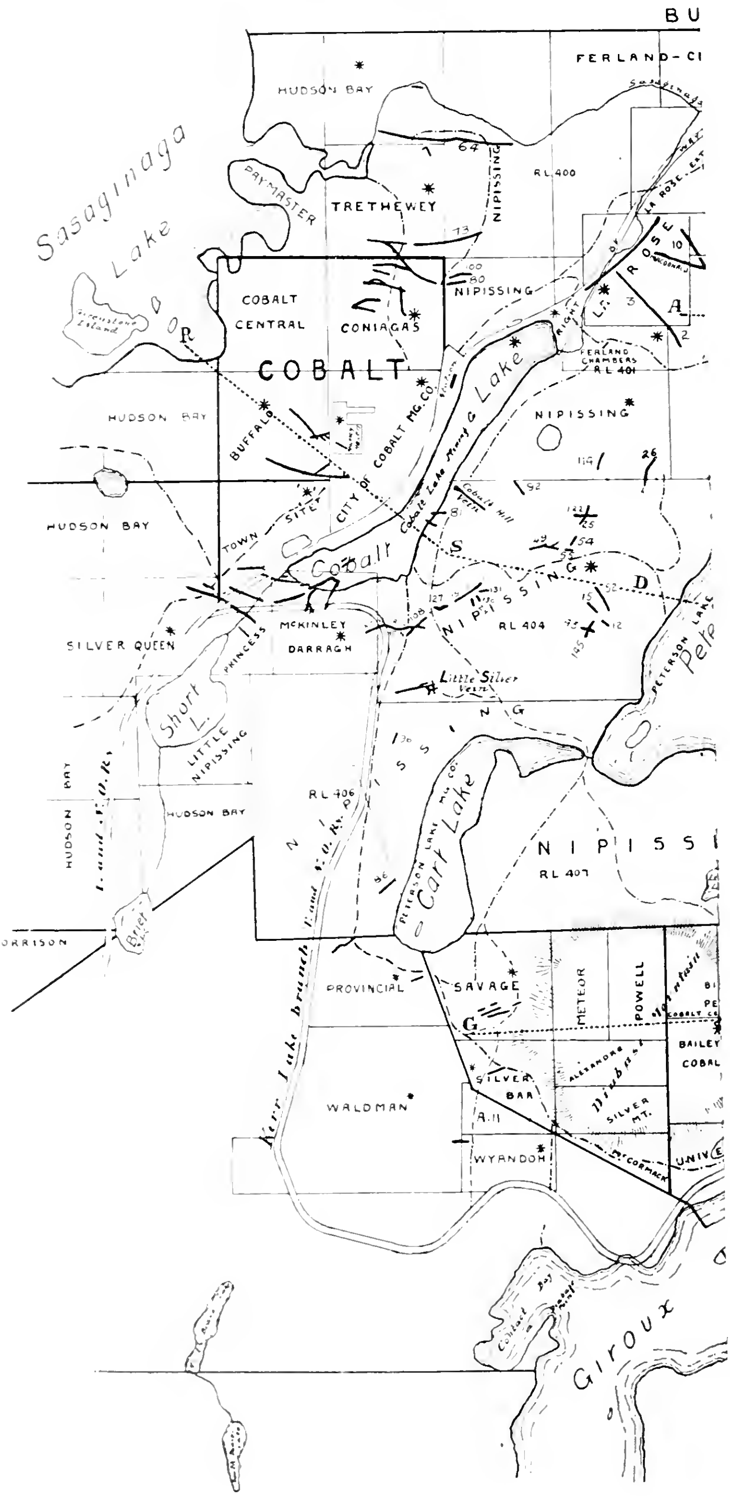
GENERALIZED VERTICAL SECTION THROUGH THE PRODUCTIVE PART OF THE COBALT AREA.

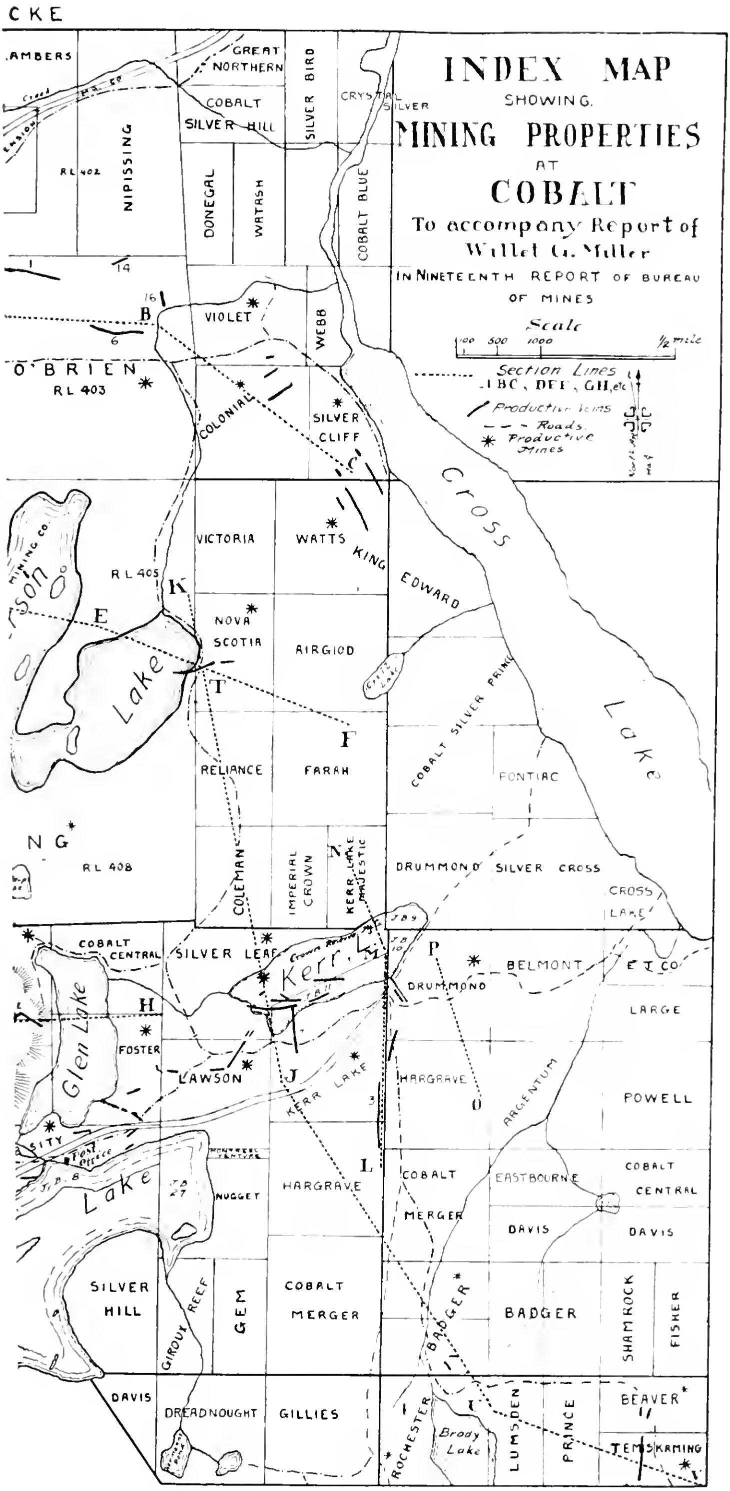
The section shows the relations of the Nipissing diabase sill to the Keewatin and the Cobalt series, and to the veins. The eroded surface is restored in the section. The sill is less regular than the illustration shows it to be.

B and C represent a large number of veins that are in the fragmental rocks, Cobalt series, in the lower or foot-wall of the eroded sill. N represents a type of vein, such as No. 26 on the Nipissing, in the Keewatin below the eroded sill, and L a type such as one under Peterson lake, in the Keewatin foot-wall, but not extending upward into the sill; K, a vein in the sill itself, such as No. 3 on the Kerr Lake property; T, a vein, such as that on the Temiskaming or Beaver properties, in the Keewatin hanging wall and extending downward into the sill.

downward from the Keewatin into the underlying, intrusive Nipissing diabase. The vein on the property, shown on accompanying maps under the name Cobalt Central, passes from the surface downward through the Nipissing diabase into the Cobalt series, which here forms the foot-wall of the diabase sill. Moreover, "blind" veins, or veins that do not outcrop at the surface, have been worked on several properties. One of the most interesting of these occurs beneath Peterson lake. This vein is in the Keewatin, which is here overlain by the Nipissing diabase sill. The vein runs up to the bottom of the sill, but not into it. Fig. 7 and the colored general cross-section, R. S. D. E. T. J. U. V., bring out the relationship of the rocks and the type veins described.

The colored cross-section mentioned shows the relationship of the rocks and veins for a distance of over four miles. It brings out the fact that the relation of the


BU
FERLAND-CI
HUDSON BAY
Sasaginaga Lake
PAYMASTER
TRETHEWEY
NIPISSING
RL 400
LA ROSE
NIPISSING
COBALT CENTRAL
CONIAGAS
COBALT
FERLAND CHAMBERS RL 401
HUDSON BAY
BUFFALO
COBALT MG. CO.
Cobalt Lake
NIPISSING
Cobalt Hill Vein
HUDSON BAY
TOWN SITE
CITY OF COBALT
Cobalt
NIPISSING
RL 404
SILVER QUEEN
McKINLEY DARRAGH
PRINCESS
Little Silver Vein
PETERSON LAKE
Short L.
LITTLE NIPISSING
HUDSON BAY
RL 406
Cart Lake
PETERSON LAKE MG. CO.
NIPISSING
RL 407
HUDSON BAY
MORRISON
Brier
PROVINCIAL
SAVAGE
METEOR
POWELL
BAILEY
COBALT
SILVER BAR
ALEXANDRA
SILVER MT.
WALDMAN
A.11
WYANDOH
McCORMACK
UNIV
Giroux


INDEX MAP
SHOWING
MINING PROPERTIES
AT
COBALT
To accompany Report of
Willet G. Miller
IN NINETEENTH REPORT OF BUREAU OF MINES
Scale
½ mile
Section Lines ABC, DEF, GH, etc.
Productive Veins
Roads
Productive Mines
GREAT NORTHERN
COBALT SILVER HILL
SILVER BIRD
CRYSTAL SILVER
NIPISSING
DONEGAL
WATASH
COBALT BLUE
VIOLET
WEBB
O'BRIEN
RL 403
COLONIAL
SILVER CLIFF
Cross Lake
VICTORIA
WATTS
KING EDWARD
NOVA SCOTIA
AIRGIOD
Lake
COBALT SILVER PRINCE
RELIANCE
FARAH
PONTIAC
COLEMAN
IMPERIAL CROWN
KERR LAKE MAJESTIC
DRUMMOND
SILVER CROSS
CROSS LAKE
COBALT CENTRAL
SILVER LEAF
Kerr
BELMONT
DRUMMOND
LARGE
Glen Lake
FOSTER
LAWSON
KERR LAKE
HARGRAVE
ARGENTUM
POWELL
NUGGET
HARGRAVE
COBALT MERGER
EASTBOURNE
COBALT CENTRAL
DAVIS
DAVIS
SILVER HILL
GIROUX REEF
GEM
COBALT MERGER
BADGER
BADGER
SHAMROCK
FISHER
DAVIS
DREADNOUGHT
GILLIES
ROCHESTER
Brady Lake
LUMSDEN
PRINCE
BEAVER
TEMISKAMING
Post Office
Lake

veins to the intrusive, flat-lying sill of Nipissing diabase is unique. The veins have not been filled by waters ascending vertically upward, as some writers on the Cobalt area have assumed; neither are the veins that are being worked the narrow parts of wide veins that penetrated the now eroded overlying rocks. It cannot be proved that any of the veins in the Cobalt area reached the surface as it existed at the time of the intrusion of the Nipissing diabase. The occurrence of "blind" veins makes it doubtful whether or not all the veins associated with the sill did not have a comparatively short vertical extension.

The deepest mines at Cobalt are the Temiskaming and Beaver. The shafts of both were started in the Keewatin, which here forms the upper or hanging wall of the sill. They have gone through the hanging wall and into the diabase.

Most of the ore in the Cobalt area has come from veins, or parts of veins, that originally lay beneath the sill, or in the foot-wall. Merchantable ore has not been found at so great a distance beneath the sill as above it. Unfortunately, however, little of the hanging wall remains, erosive agencies having removed it, together with much of the sill and the foot-wall.

The veins are described more systematically on following pages, but it was thought that an outline description in the introductory pages would be useful.

The material in these veins has, in all likelihood, been deposited from highly heated and impure waters which circulated through the cracks and fissures of the crust and were probably associated with—followed—the Nipissing diabase eruption.[6] It is rather difficult to predicate the original source of the metals—silver, cobalt, nickel, arsenic and others—now found in these veins. They may have come up from a considerable depth with the waters or they may have been leached out of what are now the folded and disturbed greenstones and other rocks of the Keewatin. Analyses of various rocks of the area have not given a clue as to the origin of the ores. However, the widespread occurrence of cobalt veins in the diabase, or in close association with it, shown by discoveries during the last seven or eight years, throughout a region three thousand square miles or more in extent, appears to be pretty conclusive proof that the diabase and the ores came from one and the same magma.

As these ore bodies in the vicinity of Cobalt station, and others in Ontario, may be said to be unique among those known in North America, we have no chance of instituting comparisons on this continent. Some European veins, however, such as those of Annaberg, Joachimsthal and other localities which will be again referred to, show a similar association of minerals.

These European ores are considered by most authors to be genetically connected with intrusions of granite. At Joachimsthal the veins are said to be cut across by basic dikes, and there is evidence to the effect that at the time of the eruption of the dikes the vein formation had not yet been completed. Since, especially nickel and cobalt minerals are characteristically genetically connected with basic rocks, the question arises as to whether the European ores mentioned may not be more closely connected in origin with basic rocks than they are considered to be. There may be deeper seated intrusions of these rocks slightly older than the dikes.

6 The waters are said to be associated or connected with the diabase eruption in the sense that they probably represented the end product of the eruption. In many volcanic regions hot springs are present long after the rocks have been solidified. In the Cobalt area the fissures and joints now occupied by the ores were probably produced by the gradual shrinkage in cooling of the diabase, the ores being deposited by the waters which represented the last stage of vulcanicity.

ORES AND MINERALS

The more important ores in the veins under consideration are native silver—associated with which is usually some dyscrasite, argentite, pyrargyrite and other compounds of the metal—smaltite, niccolite and related minerals. Many of the minerals occur mixed in the ores, and for this reason some of them have not been clearly identified. Another character of the minerals, which renders their identification difficult, is the fact that most of them occur in the massive form. Crystals when present are small, being frequently almost microscopic in size. The following minerals have been identified and can be conveniently classed under the headings:

I.—Native Elements:

Native silver, native bismuth, graphite.

II.—Arsenides:

Niccolite, or arsenide of nickel, $NiAs$; chloanthite, or diarsenide of nickel, $NiAs_2$; smaltite, or diarsenide of cobalt, $CoAs_2$.

III.—Arsenates:

Erythrite, or cobalt bloom, $Co_3As_2O_8+8H_2O$; and annabergite, or nickel bloom, $Ni_3As_2O_8+8H_2O$; scorodite, $FeAsO_4+2H_2O$.

IV.—Sulphides:

Argentite, or silver sulphide, Ag_2S; millerite, or nickel sulphide, NiS; argyropyrite?; stromeyerite? $(Ag,Cu)_2S$; bornite, Cu_5FeS_4; chalcopyrite, $CuFeS_2$; sphalerite, ZnS; galena, PbS; pyrite, FeS_2.

V.—Sulpharsenides:

Mispickel, or sulph-arsenide of iron, $FeAsS$; cobaltite, or sulph-arsenide of cobalt, $CoAsS$.

VI.—Sulpharsenites:

Proustite, or light red silver ore, Ag_3AsS_3; xanthoconite? Ag_3AsS_4.

VII.—Antimonides:

Dyscrasite, or silver antimonide, Ag_6Sb; breithauptite, $NiSb$.

VIII.—Sulphantimonites:

Pyrargyrite, or dark red silver ore, Ag_3SbS_3; stephanite, Ag_5SbS_4; polybasite? Ag_9SbS_6; tetrahedrite, or sulph-antimonite of copper, $Cu_8Sb_2S_7$; freibergite? (silver-bearing tetrahedrite).

IX.—Sulphobismuthites:

Matildite, $AgBiS_2$; emplectite, $CuBiS_2$.

X.—Mercury:

Amalgam?

XI.—Phosphate:

Apatite.

XII.—Oxides:

Asbolite; heubachite?; heterogenite?; arsenolite; roselite?

XIII.—Veinstones:

Calcite, dolomite, aragonite, quartz, barite, fluorite.[7]

7 Barite and fluorite have not been found in the veins at Cobalt proper, but they occur with silver-cobalt ores in one or two veins near Elk lake, and in Langmuir township in the southeast part of the Porcupine area. Small veins of barite have also been found in the quartz-diabase in Leonard and Lawson townships, in the Gowganda area.

The table contains a few minerals that have been found in only one or two veins and cannot be considered characteristic. Millerite, for instance, is of rare occurrence, and emplectite has been found only in the Floyd mine, near Sharp lake, in the western part of the Cobalt area. Bornite, chalcopyrite, zinc blende, galena and pyrite are not characteristic of most of the ore, these minerals occurring more frequently in the wall rock or in non-silver bearing ore of the Keewatin. As a note on a following page shows, apatite in recognizable crystals has been found in the ore of only one mine. Mercury appears to occur in the ore of all the mines that contain high values in silver, but whether it occurs only as amalgam or in other forms has not been determined. Among the veinstones aragonite is found but rarely, at least in easily recognizable form, while barite and fluorite have not been observed in the veins at Cobalt proper.

A question mark has been placed after the names of several minerals in the table which have been reported to occur in the veins but whose identification has not been made complete by chemical analyses or crystallographic measurements.

Gold in small quantity has been found in a number of veins, especially in those in which cobaltite or mispickel are characteristic minerals. Certain shipments from the Temiskaming mine contained copper in economic quantities.

A characteristic of the group is the subordinate part which sulphur plays in comparison with arsenic. Antimony, which is not abundant, is found in some compounds where we would expect to find arsenic, since the latter is so much more abundant. For instance, while we have both native silver and arsenides in abundance the compounds of arsenic and silver occur only in small quantity. Then one would also expect to find more compounds of bismuth since this metal occurs in the free state in considerable quantities in some parts of the deposits. It might also be expected that native arsenic would occur at times.

It will be seen from a following page that nearly all the chemical groups of minerals found in the celebrated Joachimsthal deposits of Bohemia are present in the Temiskaming ores. The most important exception is uraninite or pitchblende, which came into prominence a few years ago on account of its being the chief source of the element radium. The Austrian Government, finding they had a practical monopoly of pitchblende, are reported to have prohibited its export.[8]

The Bohemian deposits appear never to have been so rich in silver, cobalt, nickel or arsenic as are those of Ontario.

Order of Deposition of Minerals

The following table shows, in descending order from the youngest to the oldest, the general succession in the order of deposition of the principal minerals of the Cobalt area proper. There appear to be, however, minor exceptions to this order.

III. Decomposition products, *e.g.*, erythrite or cobalt bloom, annabergite and asbolite.
II. Rich silver ores and calcite.
I. Smaltite, niccolite and dolomite or pink spar.

After the minerals of group I. were deposited the veins were subjected to a slight movement. In the cracks thus formed the minerals of group II. were deposited. A few veins that escaped the disturbance do not contain silver in economic quantity.

This order of deposition appears to be the same as that of the minerals in the Annaberg deposits of Germany and those of Joachimsthal, Austria.[9] At Annaberg the

[8] The reserves of pitchblende in the Joachimsthal ore deposits, scientifically defined, are very small. Only a few tons are produced per annum, and these yield 2 or 3 grammes of salts of radium. Earlier less was produced, for the process of production was confined simply to obtaining radium without special attention to other radio-active elements. But, beginning with the year 1910, a more active and scientifically-organized production of radio-active substances was begun. Of all the pitchblende exploited up-to-date, the Joachimsthal ore is relatively the richest in radium. But the quantity of radium contained in it is exceedingly small. Two tons of ore yield only a few hundredths of a gramme of chloride of radium. Therefore, the labour of obtaining combinations of radium is confined almost to the capture of its atoms. The labour is very great, and its cost is colossal. The world's annual production of the salts of radium is 3 to 5 grammes, and £20,000 is the price per gramme. The "Mining Journal," London, Feby. 8th, 1913, p. 134.

[9] Beck, The Nature of Ore Deposits, Weed's translation, pages 285, 289.

uranium ore or pitchblende is said to have been deposited earlier than the rich silver ores and later than the cobalt-nickel minerals, while barite, fluorite and quartz were deposited prior to the latter. At Annaberg there are thus considered to have been broadly five periods of deposition, while at Cobalt there have been but three, minerals representing the first and third periods being absent.

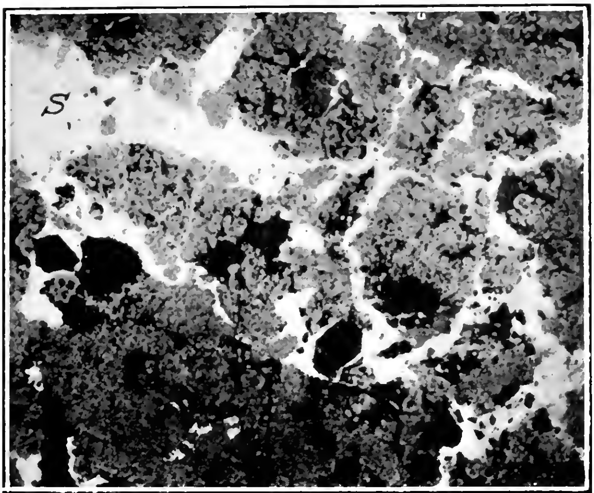


Fig. 8.

Polished surface of ore from La Rose Mine, Cobalt. The native silver, S, is the white material in the illustration. The large black spots are calcite, the small black ones niccolite, and the grey is smaltite.

Fig. 8a.
Native silver.

Messrs. W. Campbell and C. W. Knight subjected specimens of the cobalt-silver ores to examination, using methods employed in metallography.[10] While their results confirm, in a general way, the author's observations on hand specimens and on blocks of ore, they have worked out the order of deposition of the minerals in greater detail. They say: "Although all of the structures met with in this examination cannot be satisfactorily explained, they point to the following order of origin for the principal constituents: First came the smaltite, closely followed by the niccolite; other minerals in small amount came down at this time. Then, after a period of slight movement in which the first minerals were more or less fractured, calcite was deposited as a groundmass. Later came argentite, which was followed by native silver and native bismuth. Lastly came the surface decomposition products, erythrite and annabergite.

"Arranged in tabular order, the succession is then as follows:

"Smaltite.
"Niccolite.
"*Period of movement and fracturing.*
"Calcite.
"Argentite.
"Native silver.
"Native bismuth.
"*Period of decomposition.*
"Erythrite and Annabergite."

At Annaberg bismuth ore is thought to have been deposited with the cobalt-nickel minerals and not with the rich silver ore. Moreover, at the time Messrs. Campbell and Knight made their examination of the ores from Cobalt it was not known that two carbonates occur as veinstones, viz., calcite and dolomite or pink spar. The latter has been found to belong to an older generation than the former. It may be added that, while much of the niccolite is later in order of deposition than the smaltite some of the former mineral appears to have been deposited earlier than some of the latter.

Any statement as to the form in which the native silver came in solution into the veins must be merely hypothetical. The author is inclined, however, to the view that much of this silver, at least, should be considered as a primary deposit from solutions that worked through the veins after they had been fractured and disturbed. It does not seem necessary to conclude that most of the native silver has been derived from the decomposition of compounds of the metal in the veins. Since it is associated with calcium carbonate it does not seem impossible that the silver circulated through the fissures as a double carbonate, being precipitated in the metallic form when conditions of pressure and temperature were favorable, and suitable precipitants were encountered. J. H. L. Vogt, for instance, regards a solution of silver carbonate, or bicarbonate, as the source of the metal in the Kongsberg veins, probably because of its association with calcite, and thinks that ferrous compounds or carbonaceous substances are the precipitants.[11]

Silver carbonate, Ag_2CO_3, like calcium carbonate, $CaCO_3$, is soluble in excess of carbon dioxide, CO_2. Hence when the calcite, $CaCO_3$ of the cobalt-silver veins was being carried in solution, it does not seem improbable that silver carbonate may have been in solution at or about the same time.

An interesting paper, recently written by Messrs. Chase Palmer and Edson S. Bastin, discusses "Metallic Minerals as Precipitants of Silver and Gold."[12] "The preliminary experiments here described show that certain sulphides and arsenides of copper and nickel precipitate metallic silver very efficiently from dilute aqueous solutions of silver sulphate. . . .

10 (1) Microscopic Examination of the Cobalt-Nickel Arsenides and Silver Deposits of Temiskaming. Ec. Geol., Sept.-Oct., 1906.
(2) The Paragenesis of the Cobalt-Nickel Arsenides and Silver Deposits of Temiskaming. Eng. and Min. Jr., June 9th, 1906.
11 The Data of Geochemistry, by F. W. Clarke. Bulletin 491. U.S.G.S. J.H.L. Vogt., Zeitschr. prakt. Geologie, 1899, pp. 113, 177.
12 Economic Geology, March 1913, p. 140.

"The more common sulphides, such as pyrite, galena, and sphalerite were relatively inactive as precipitants of silver from aqueous solutions of its sulphate."

Argentite, proustite and native silver, in hair-like crystals, appear at times, judging from their mode of occurrence, to be of secondary origin. These minerals are found in vugs or open spaces characteristically in the lower workings of the mines where the ore has become leaner or below the productive zone in the veins. Practically all the samples of native silver, excepting those that show a crystalline form, or occur in veinlets, contain mercury. It may be added that a minor quantity of native silver in veinlets is later in age than the more massive, less pure variety.

The silver-bearing solutions working downward beneath the sill, in the fractured veins, lost their silver content by precipitation on coming in contact with cobalt-nickel minerals before a great depth was reached. Hence, it is not surprising to find that rich silver ore does not extend to as great a depth beneath the sill as do the cobalt-nickel ores. Moreover, where a vein extends downward from the Cobalt series into the Keewatin, the part of it in the former series frequently appears to have been more fractured and disturbed, after the deposition of the cobalt-nickel minerals and before the deposition of native silver, than the part of it in the underlying tougher and more massive Keewatin. In such a case, silver-bearing or other solutions could not penetrate so readily the part of the vein in the Keewatin as the part of it in the Cobalt series.

Notes on Minerals

Native Elements

NATIVE SILVER

The greater part of the native silver of the Cobalt and surrounding areas is usually impure from the presence of antimony and other metals. It is closely associated with dyscrasite, and the mixture of the two minerals contains mercury, doubtless in the form of amalgam or other closely related compound.[12a] Much of the native silver occurs in cracks in the earlier deposited minerals—smaltite, niccolite and calcite or dolomite. It frequently forms veinlets in the wall rock of the veins, especially in the diabase. Boulders of granite, a foot or more in diameter, in the conglomerate through which the veins cut at the Coniagas, Trethewey and other mines have been found with delicate veinlets of silver running through them.

While the silver does not usually occur in crystal form, it has been found in two or three veins in fairly well developed octahedrons. It also occurs occasionally in coarse, intergrown, filiform crystals, and in mossy forms. Usually, however, the mineral is found in masses or slabs, flakes and films. Hair silver is found in vugs.

The percentage of silver in certain museum samples and in shipments of ore is given on following pages.

The silver appears to represent two, or more, periods of deposition. The purer, better crystallized, less common variety seems to have been deposited in some cases, at least, later than the more impure.

Figs. 8, 9, 10 are from photographs of native silver.

12a " . . . . the ordinary high-grade ore of the district usually carries from two to five pounds of mercury per ton of ore, depending upon the metallics contained. Tests were made on the metallics alone; 21 samples of metallics taken from various Nipissing veins and from three other mines showed mercury in every case, the result varied from 8 to 95 lb. mercury per ton of metallics, and averaged 35 pounds." Nipissing High Grade Mill, Cobalt, by R. B. Watson, Eng. and Min. Jr., Dec. 7th, 1912.

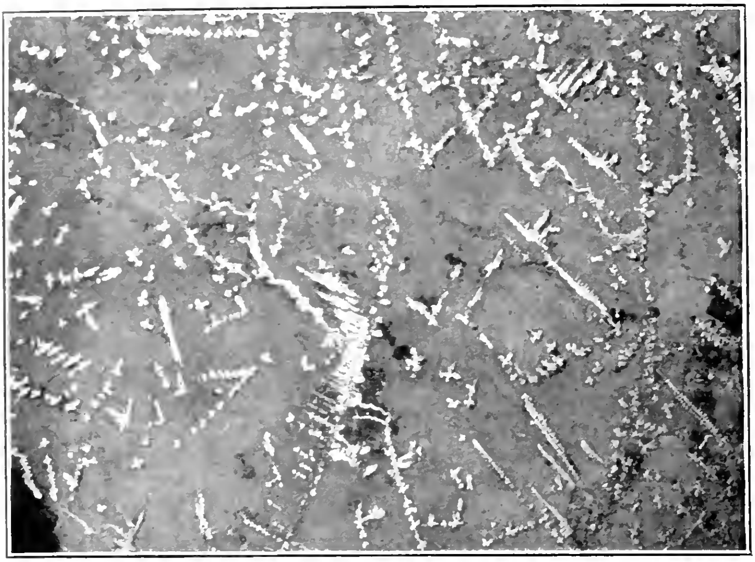


Fig. 9. Native silver in calcite, slightly reduced in size, Temiskaming mine, Cobalt.

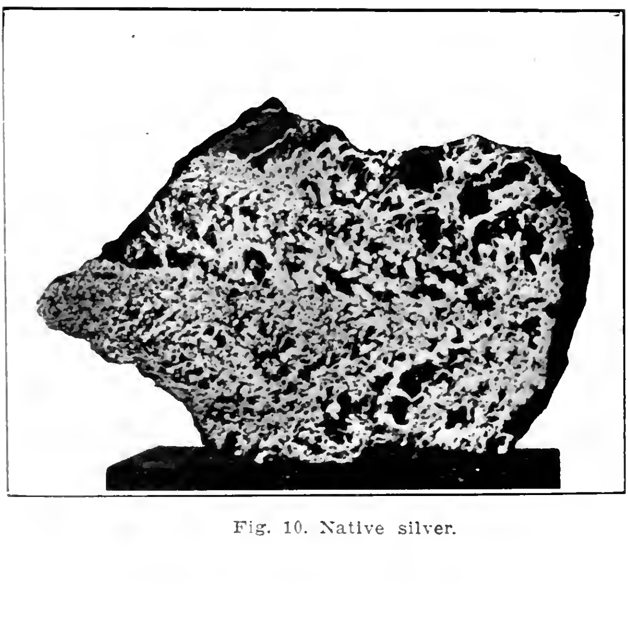


Fig. 10. Native silver.

NATIVE BISMUTH

Native bismuth has been found in practically all the veins which have been opened up. On freshly broken surfaces it has almost the color of native silver but is more readily cut. It soon tarnishes on exposure to the air and takes on a rather striking yellowish or reddish color, somewhat like that of pyrite or bornite.

	Per cent.
Bismuth	99.20
Cobalt	distinct trace
Nickel	trace
Iron	.40
Silver	trace
Arsenic	trace
Antimony	none
Total	99.60

This analysis represents a sample from the Cobalt Hill vein on the Nipissing property.

Fig 11.—Spheroidal intergrowth of smaltite and calcite, almost natural size. The smaltite is lighter in color than the calcite in the illustration.

GRAPHITE

This mineral was closely associated with the ores of the Cobalt Hill vein, on the Nipissing property. The main shaft of La Rose mine passed through a zone of rock highly impregnated with it at a depth of 200 feet or over. Certain schists, that have been classed as of Keewatin age but which may belong to the Grenville, are highly impregnated with graphite.

Arsenides

SMALTITE

Much of the massive smaltite of the veins when carefully examined, or when submitted to chemical analysis, proves to be impure from the admixture of niccolite and other minerals. Nickel also replaces cobalt and the mineral graduates towards chloanthite. Occasionally smaltite is found in small, well-formed crystals (Figs. 11, 13).

NICCOLITE

A sample from La Rose mine, consisting essentially of niccolite, was found to contain 5.02 oz. of silver to the ton, and nickel 26.64, cobalt 6.16, arsenic 45.64 per cent.

Niccolite, smaltite, and native silver are the most characteristic minerals of the veins.

BREITHAUPTITE

This mineral is found in La Rose, Hudson Bay and other veins. There is apparently a graduation from it to niccolite by the substitution of arsenic for antimony.

CHLOANTHITE

A sample of chloanthite, in nodular form, from La Rose mine, J S 14, was found to have the following composition:

	Per cent.
Nickel	23.24
Cobalt	4.11
Silver	2.78
Sulphur	2.18
Arsenic	67.17
Antimony	none
Total	99.48

The chloanthite occurs characteristically in small nodular or spheroidal masses in calcite.

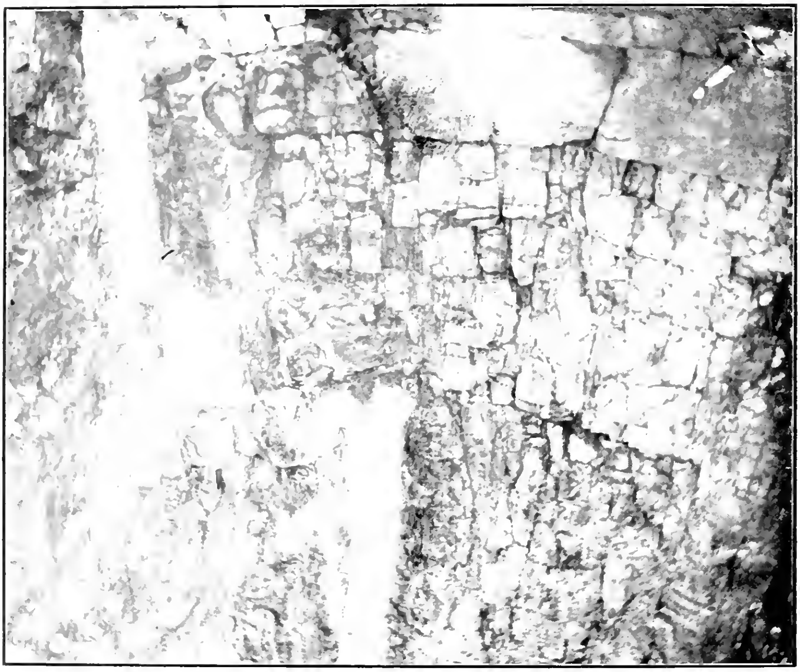


Fig. 12. Cobalt Hill vein, northwest corner of location R L 404, Nipissing mines. The photograph shows the fractured character of the rock and a gentle anticline. The vein is seen to be in step-like forms as if it had been affected by horizontal faults, but the ore is not brecciated.

Additional Notes on Arsenides

In order to show the character of the more massive cobalt-nickel ore of the area, a description of the vein known as Cobalt Hill may be given. This vein was one of the first four found in the area. Unlike the other three, and most of the cobalt-nickel veins since discovered, it did not contain silver in economic quantity, owing apparently to its not having been subjected to secondary disturbance. The vein is near the shore of Cobalt lake, in the northwest corner of location R.L. 404, on the Nipissing property. Its strike is northwest-southeast.

The more or less well banded slate-like greywacké, through which the Cobalt Hill vein cuts perpendicularly, dips westward towards Cobalt lake at an angle of 20 or 30 degrees in the direction in which the vein strikes. The rock is slightly arched over the vein, thus producing a gentle anticline, which pitches towards the lake (Fig. 12). The vein is at a height of 100 feet above the lake.

At the points where it was originally exposed, the vein showed a width of 14 inches of massive ore, and vugs two feet or more in the wall rock from the edge of the vein contained cobalt bloom. It may be added that in certain of the other veins the wall rock is impregnated with native silver, which is found even in the centre of boulders of granite in the conglomerate.

Very little veinstone, such as calcite or quartz, is present. When examined carefully in hand specimens, this apparently massive, uniform, gray ore is found to contain essentially two constituents. Set through the gray ground mass are grains of the copper colored niccolite, the ground mass itself being smaltite. Occasionally the smaltite in tiny vugs shows crystals large enough to be recognized. Minute crystals of smaltite also occur in the wall rock. No crystals of the niccolite have been recognized. There are probably some other closely related arsenides of cobalt in addition to smaltite in this ore. The diarsenide of nickel, chloanthite, is also present. At times some massive tetrahedrite is seen, and it is usually associated with copper pyrites, which assists in its identification. It is, however, usually readily recognizable by its black color and bright appearance.

Much of the surface of this ore shows the decomposition product, cobalt bloom, the arsenide having been changed by atmospheric agencies to the arsenate, the oxidized form. There is at times some green decomposition material, which is the arsenate of nickel, known as annabergite. Occasionally the cobalt bloom shows a crystalline structure, being in the form of delicate rosettes. The bloom, which is of a delicate pink color, can be easily recognized, if one has any difficulty in distinguishing it from certain shades of red oxide of iron, by heating it gently, when it will take on a blue color. This is characteristic of all hydrated salts of cobalt. They are pink or, if in dilute solutions, almost colorless. Sympathetic ink, for instance, is a dilute solution of cobalt salt. If a pen be dipped into it and used for writing on paper, the writing is invisible until the paper is heated, driving off the water and dehydrating the salt, which then takes on a distinct blue color.

In most of the veins where silver is found in important quantities, a uniform massive structure like that of the vein just referred to is not exhibited. There is more or less calcite present, and at times a little quartz. The veins sometimes show a crudely banded structure.

Smaltite, and the corresponding arsenide of nickel, chloanthite, are said by most authors to pass into each other by the substitution of cobalt for nickel and *vice versa.* Niccolite, in the analyses quoted by Dana and others, carries only a small percentage of cobalt and iron, while smaltite frequently contains a considerable percentage of nickel and iron. In the ore under consideration the cobalt and nickel appear to be, for the most part, in distinct compounds. In the analysis (No. 1), if we consider the 7 per cent. of nickel to exist as niccolite, and the percentages of iron and cobalt, 6.3 and 16.8 respectively, to represent smaltite, the theoretical percentage of arsenic in the ore should be 68.47 instead of 69, as found by analysis. The percentage of niccolite

Analyses of Cobalt Hill Ore

Constituent	1	2	3	4	5
Cobalt	16.8	16.7	16.76	19.80	21.70
Nickel	7.0	6.8	6.24	4.56	
Iron	6.3	7.5	....	6.20	8.89
Arsenic	69.0	62.0	66.60	60.30	63.55
Sulphur		7.0	3.37	4.09	5.38
Insol. silica, etc.	0.9	....	....	2.40	0.60
Water	....	....	....	2.00	....
Totals	100.0	100.0	....	99.35	100.12

by weight would be 15.94, or about one-seventh part of the whole by volume, since niccolite has a somewhat higher specific gravity than smaltite.[13] Specimens of this ore when examined with the magnifying glass, appear to agree with this.

Of the above analyses, Nos. 1 and 2 were made by Mr. O. S. James. The former represents a hand specimen from near the surface, and the latter a specimen from a depth of about 20 feet; 3 and 4 are of average samples collected by the writer, the former from the uppermost opening on the hill, and the latter from the middle or main opening, the analyst being Mr. A. G. Burrows. Sample 3 contained considerable cobalt bloom. Analysis 5 is by Dr. J. Waddell. It represents a specimen collected by Prof. Nicol. This specimen was not taken, like 3 and 4, with the object of determining the average composition of the vein. Prof. Nicol states that a qualitative analysis showed the presence of small amounts of copper and lead, and the absence of antimony, bismuth and zinc.

Minute, brilliant, silver-white, or tin-white, crystals, occur sparingly, imbedded in the wall-rock and in the ore. The crystals are cubes and combinations of this form,

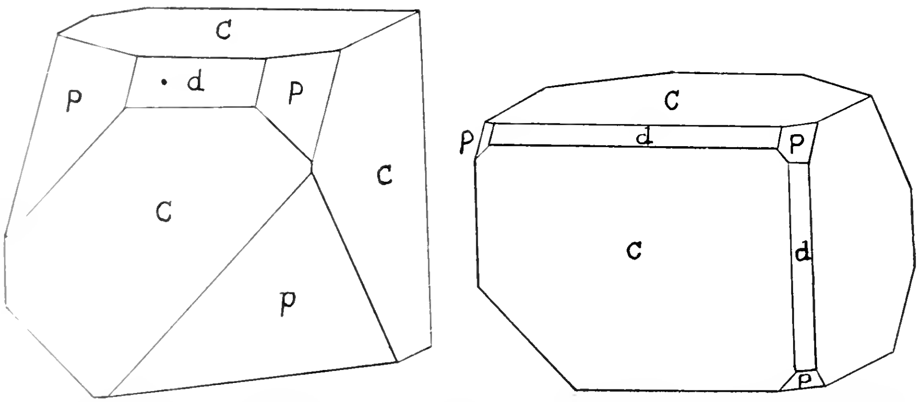


Fig. 13. Smaltite crystals from the Cobalt Hill vein, Nipissing mines, measured and drawn by Prof. William Nicol of the Kingston School of Mining. C = cube, P = octahedron, d = rhombic dodecahedron.

with the rhombic dodecahedron, and octahedron. Prof. Nicol, who has measured some of them on the goniometer, has found them to be smaltite (Fig. 13). The white or gray colored arsenides show a tendency to form globular or spheroidal masses, with a radiated structure. Some of these masses in calcite have a diameter of over half an inch.

The ore is at times somewhat porous, spaces being left between the globules, which are tarnished almost black on their surfaces. Where the surface of the ore has been exposed to the action of water or ice, it has a dark color not unlike that of the wall rock, bloom, the product of decomposition, having been carried away. The ore is coated with a fraction of an inch of the dark decomposed material.

Small grains of quartz are found sparingly in the ore.

Copper pyrites, with which is usually associated gray copper ore, tetrahedrite, is found in the deposit. Native bismuth is also of frequent occurrence.

Veinlets at Lake Shore

Two veinlets, at the time the camp was discovered, were to be seen near the water level on the east side of Cobalt lake, not far from the point where the north boundary of location R L 404 meets the shore. A sample was taken from these veinlets and was found to have the following composition, showing that it is much like the massive ore on the Cobalt Hill vein.

13 Specific gravities: niccolite 7.33-7.67, smaltite 6.4-6.6, native silver 10.1-11.1. It may be added that a determination of the specific gravity of a number of samples of ore from one of the cobalt-silver veins showed it to average 4.85.

	Per cent.
Cobalt	17.84
Nickel	4.16
Arsenic	56.10
Sulphur	5.98
Iron	9.22
Insoluble	4.32
Bismuth	No indications
Silver	No indications
Antimony	No indications
Water	Not determined

Sample shows cobalt bloom.

Arsenates

COBALT BLOOM OR ERYTHRITE

Mr. W. F. Green has made a detailed examination of some of the crystallized bloom and given a full description of the faces present.[14]

The bloom found generally in the veins is the earthy variety and seldom shows good crystallization. Mr. Green describes the material examined by him as follows:

"The crystals occur in the form of a druse, and are attached to the matrix by one end of the vertical axis. They are small, and where examined closely most of them are found to be a growth of thinner crystals in approximate parallel position."

ANNABERGITE

This secondary mineral, at times known as nickel bloom, occurs in most of the veins. When intermixed with cobalt bloom its color is masked.

WHITE BLOOM

Associated with the cobalt bloom in the weathered parts of La Rose and other veins there is a white, clay-like material, which resembles in form the moist cobalt bloom. The writer suspected that the white color of this material was due to the intermixture of the green nickel arsenate, annabergite, with the pink cobalt bloom. An analysis by Mr. Burrows confirmed this opinion. It is a rather interesting occurrence. In pottery the blue cobalt compounds are used in small quantities to destroy the delicate reddish tonge due to iron in the ware. In this white bloom one color is destroyed by another in nature.

	Per cent.
Nickel oxide	29.30
Cobalt oxide	6.43
Arsenic pentoxide	38.31
Lime	.84
Magnesia	1.12
Iron	.30
Water	24.04
Total	100.34

Mr. Burrows says: "In evaporating the solution of the metals I had a very interesting result. The solution was quite concentrated, and on cooling, green acicular crystals of the nickel compound separated out, while the solution above and around them was quite pink. The original solution before the crystallizing out of the nickel compound was quite blue."

14 Trans. Can. Inst., Toronto, Vol. VIII, part 3, April, 1909, pages 443-450.

Sulphides

ARGENTITE

This mineral occurs in most of the veins but is not so common, nor does it occur in such quantity, as native silver. While usually without crystal form, at times it occurs in well developed crystals, of larger size than those of any other metallic minerals in the veins.

MILLERITE

This mineral is very rare in hair-like crystals and has not been observed in other forms.

Sulpharsenides

COBALTITE

Under some conditions, this mineral is difficult to distinguish from smaltite. Its presence in certain of the Cobalt veins, notably the Temiskaming Cobalt mine, afterwards known as the Agaunico, and in the Columbus has been definitely determined. No. 1 represents the result of an analysis, by Mr. J. S. DeLury, of crystals from the latter mine and No. 2 ore from the former. The latter sample carried $5.20 in gold to the ton. Good crystals were found at the Columbus.

	(1)	(2)
Iron	4.55	not det.
Arsenic	44.55	41.65
Sulphur	20.73	17.18
Cobalt	29.10	32.42
Nickel	.97	....

MISPICKEL

Mispickel is not so common in the deposits as one might expect it to be. In some of the veins first discovered on what is now known as the Buffalo mine, in the town plot of Cobalt, mispickel seems to be a characteristic mineral.

	(1)	(2)	(3)
Iron	34.4	26.76	28.83
Arsenic	46.	41.76	40.08
Sulphur	19.6	17.63	19.25
Cobalt	....	3.21	4.83
Nickel	....	.76	....
Silver	....	....	306.1 oz. per ton

No. 1 shows the theoretical composition of mispickel; Nos. 2 and 3 are analyses of mispickel from the south vein (of the two discovered in 1904) on the Buffalo mine. This ore occurs in the Cobalt series not far from the contact with the Keewatin.

In connection with these the following analyses, Nos. 1 and 2, of samples of mispickel from the Big Dan and Little Dan claims near Temagami will be of interest.

	(1)	(2)
Iron	29.68	29.84
Arsenic	36.24	36.81
Sulphur	18.99	18.77
Insoluble	13.52	13.02
Water	.72	.79
Cobalt	....	....
Nickel	....	....

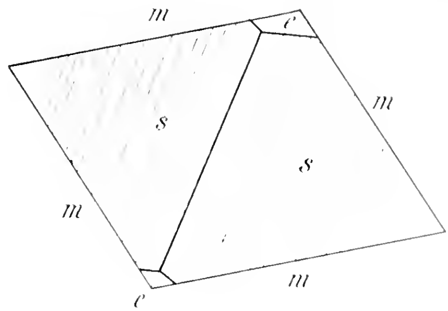


Fig 3a

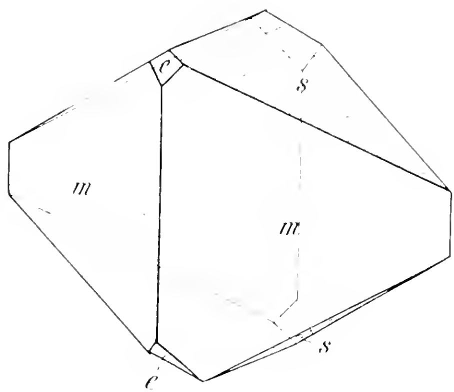


Fig 3b

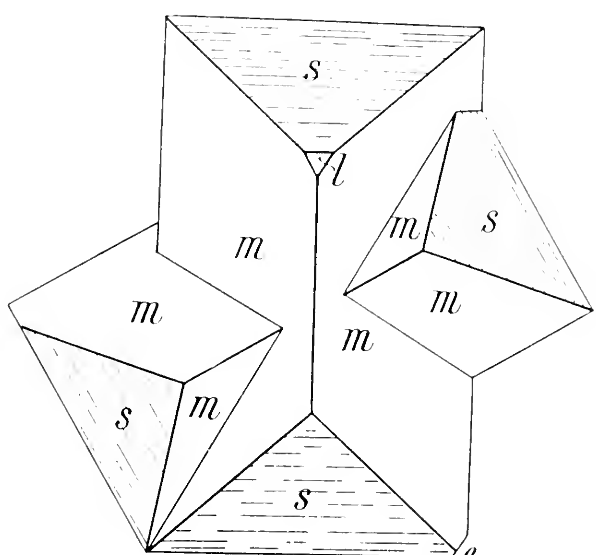


Fig 4

Fig 14 (3a, 3b, 4). Crystals of Mispickel.

No. 1 represents selected particles from a sample taken at the Little Dan claim. In addition to the components shown, the sample carried $4.00 worth of gold and 59 cents worth of silver per ton. No. 2 represents selected particles from the Big Dan claim. This ore showed values per ton of $3.20 in gold and 54 cents in silver. The deposits are in the Keewatin.

Crystals of Mispickel

The following notes on crystals of mispickel or arsenopyrite have been kindly supplied by Prof. Nicol.

"From the Cobalt district, which has produced so many interesting minerals, the mineral glaucodot, on the authority of chemical analysis, has been reported. It seemed desirable to confirm this report by a crystallographic examination of some crystals admittedly orthorhombic. During a visit to Cobalt in the spring of 1910, the writer obtained from Mr. Arthur A. Cole a number of well-formed crystals which it was supposed might prove to be glaucodot.

"A chemical examination, however, showed that the little crystals contained only iron, sulphur and arsenic, and no cobalt, and were therefore to be regarded as arsenopyrite or mispickel. This is somewhat surprising, owing to the occurrence of this mineral in a cobaltiferous vein.

"The arsenopyrite crystals are perfectly formed individuals and occur imbedded in a clayey mass in a cobaltiferous vein at the Keeley mine, in South Lorrain. They occur as simple crystals, twins, trillings, and also irregular groups. Several were measured in order to determine the forms present, the twinning law and the crystallographic elements. In Figs. 14 and 15 (3, 4 and 5) are pictured a simple crystal, a twin and a trilling, as nearly as possible true to nature.

"The forms $S=0\frac{1}{2}(012)$ and $M=\infty(110)$ in all cases determine the habit. In some cases the prism M is larger, in other cases smaller, than the dome S, thus causing variation in habit. The forms $e=10(101)$ and $l=01(011)$ occur with very small, unimportant faces.

Crystal I:

A simple crystal; dimensions 1 . 1.5 . 2 mm.

Fig. 3a shows the crystal as top view. Fig. 3b in perspective.

Combination:

m, s equally developed.

e small.

Crystal II:

Penetration twin.

Dimensions of the group 2 . 2 . 1 mm.

Twinning plane $e=10(101)$.

Fig. 4 shows this crystal as top view, projected on the face $a=0\infty(010)$ common to the two individuals.

Combination:

m, s, predominating.

l, e, small.

Crystal III:

Penetration trilling.

Dimensions of the group 1.5 . 1 . 1 mm.

Twinning plane here also $e=10(101)$.

It has only the forms $m=\infty$ (brilliant).

$s=0\frac{1}{2}$ (striated), about equally developed. The three individuals of the group are of about the same size.

Fig. 5a shows the trilling as top view, projected on the face $a=0\infty$ (010) common to the three individuals.

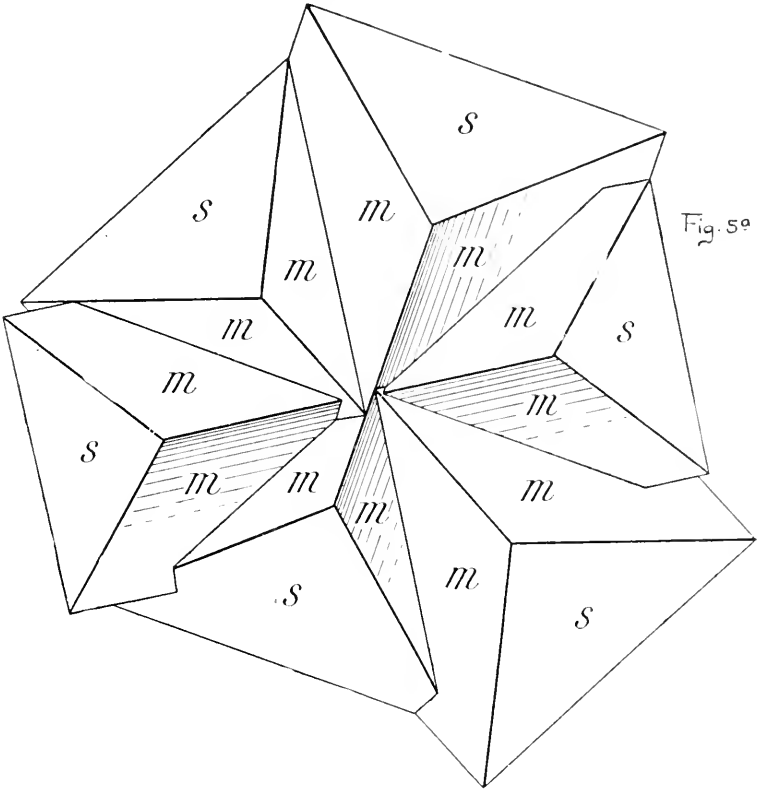


Fig. 5a

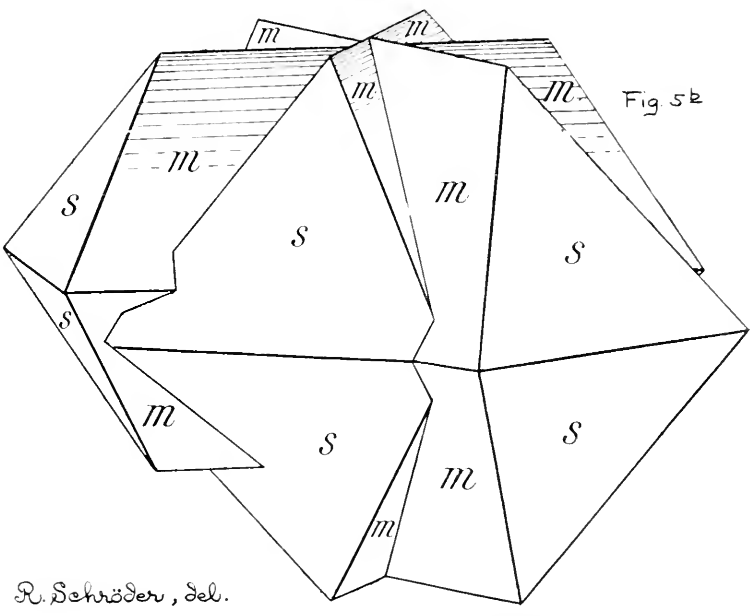


Fig. 5b

R. Schröder, del.

Fig. 15 (5a, 5b). Crystals of Mispickel.

Fig. 5 shows the trilling in perspective.

"The drawings were made with great care, as nearly as possible true to nature, by R. Schroeder, of Heidelberg.

Elements:

"As shown by the investigations of Arzruni and Baerwold, the elements of arsenopyrite vary much, especially the prismatic angle m m.* According to these authors this depends upon the varying proportion of $Fe\,S_2$: $Fe\,As_2$ of the arsenopyrite of the various localities.

"Our arsenopyrite from Cobalt gives as an average:

m m=67° 36′

s s=61° 36′

From these angles the elements:

$$\left.\begin{array}{l} ps=1.7809 \\ qs=1.1922 \end{array}\right\} a:b:c=0.6694:1:1.1922 \text{ are obtained.}$$

"Therefore it is placed at the end of the row which according to Arzruni has the highest percentage of $Fe\,As_2$.

"It is desirable to have from the crystals of the presently described locality a definite quantitative analysis, in order to decide whether Arzruni's statement regarding the connection between composition and crystalline form holds in this case. To accompilsh this, however, would require the collection of much more material than is available."

Sulpharsenites

PROUSTITE

This mineral appears to be more characteristic of veins in the diabase than of those in the other rocks at Cobalt. It occurs in small quantity.

XANTHOCONITE

This sulph-arsenite of silver is believed by Prof. Nicol to be present in certain of the Cobalt ores in the form of minute crystals, which have not, however, been measured or analyzed.

Antimonides

DYSCRASITE

A sample of dyscrasite from La Rose mine was found by Mr. Burrows to have on analysis the formula $Ag_6\,Sb$. The more common variety of this material in other districts has the formula Ag Sb.

Another sample was analyzed by Mr. N. L. Turner, with the following result, showing it to be Ag Sb.

Silver	83.90
Antimony	15.60
Arsenic	very small amount
Cobalt	trace
Total	99.50

The most striking samples of dyscrasite probably came from a vein on the Kerr lake property, near the shore of the lake and at the surface of the vein. The vein also contained very beautiful samples of native silver, associated with argentite. Dyscrasite is of fairly common occurrence in the veins in association with native silver. Much of the latter contains antimony. Amalgam is apparently associated with much of the dyscrasite of the Cobalt veins.

*Zeitschr. f. Kryst. 1878, 2.430; 1883, 7.337.

BREITHAUPTITE

This antimonide of nickel is present in some of the veins and passes into niccolite by the substitution of arsenic for antimony.

Sulphantimonites

PYRARGYRITE

This mineral is of rare occurrence in the veins at Cobalt.

The following note on the pyrargyrite crystals from La Rose mine is by Prof. Nicol:

" The crystals occur as an incrustation on the surfaces of chinks or cracks in the country rock intimately associated with argentite or silver glance.

" The crystals are more or less well developed hexagonal prisms, terminated in some cases by rhombohedrons and scalenhedrons. The crystal reproduced in the drawings shows a somewhat peculiar development—only five faces of the prism of the first order *a* are present; the sixth face *b* is a single representative of the prism of the second order."

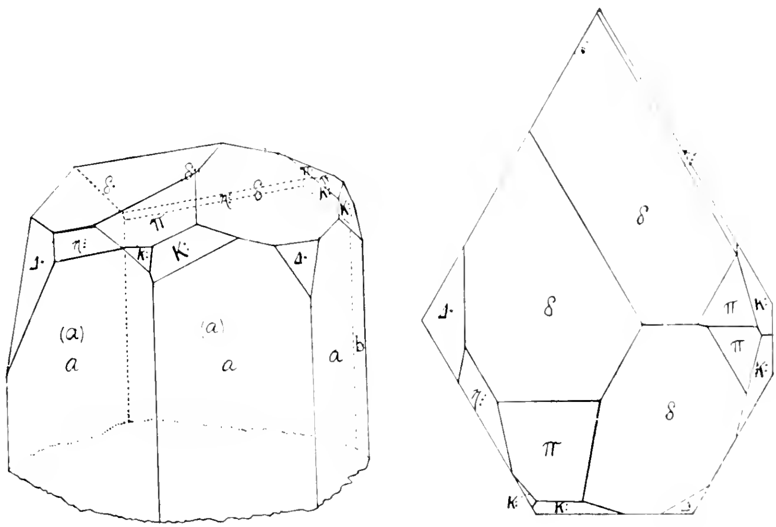


Fig. 16.

Pyrargyoite Crystal.

POLYBASITE

Prof. Nicol believes that the occurrence of this mineral in the Cobalt deposits is pretty well established, but sufficient material for analysis has not been obtained.

STEPHANITE

During a visit to Cobalt, Prof. Nicol, through the kindness of Capt. John Harris, of the Colonial mine, obtained a specimen carrying many small glistening stephanite crystals. These lie separately on crystallized calcite, which is the filling of a vein and encloses native silver. The following notes were given by Prof. Nicol:

" Stephanite has frequently been reported from the Cobalt district along with other silver ores, such as dyscrasite, pyrargyrite, proustite, argentite, matildite and polybasite. Several of these, however, have been determined simply by the use of the blowpipe. It therefore seemed worth while to subject such good material to a crystallographic examination. The measurements were made under Prof. Goldschmidt's direction on the two-circle goniometer and the drawings were made by Prof. Goldschmidt's assistant, R. Schroeder.

"One small but perfectly formed crystal, with forty-odd faces, was measured. This proved to be a trilling according to the known law for stephanite: twinning plane, a prism face o= ∞ .(110). The crystal may be described as follows:

Dimensions: 1 . 1 . 1.5 mm. Fig. 17 (1a) shows a top view of the crystal; Fig. 17 (1b) is a perspective picture.

"Observed forms:

Letter:	c	b	o	τ	t	k	d	e	𝔠	q·	m·	h·
Symbol:	0	0∞	∞	$\infty 3$	$0\infty\frac{2}{3}$	01	02	04	$\frac{1}{2}0$	$\frac{1}{4}$	$\frac{1}{3}$	$\frac{1}{2}$
Miller:	001	010	110	130	023	011	021	041	102	114	113	112

Letter:	P·	r·	w·	?C	K·	f·	𝔤:	v:	ϑ:	ω:	𝔫:
Symbol:	1	2	13	16	$\frac{1}{5}1$	$\frac{1}{3}1$	24	$\frac{1}{2}\frac{3}{2}$	$\frac{1}{2}\frac{5}{2}$	$\frac{1}{4}\frac{3}{4}$	$\frac{1}{5}\frac{\bar{3}}{5}$
Miller:	111	221	131	161	155	133	241	132	152	134	135

"All these forms were already known. All are certain with the exception of C.

Large:	c	b	o	P·	d·	r·	ω·	
Medium:	τ	k	m·	h·	m·	v·	ϑ:	
Small:	t	e	𝔠	q·	K·	f·	𝔤:	𝔫:
Uncertain:	C·							

"Combinations.

Crystal I: c b o τ t k d e 𝔠 q· m· h· P· r· w· C· K· f· v· ϑ: ω: 𝔫:
Crystal II: c b o . . . d . . . . h· P· r· . . . . 𝔤· ϑ:
Crystal III: b

MIXED DARK MINERAL

There is a mineral, or mixture of minerals, of fairly common occurrence in some of the narrow stringers which run off from the main La Rose vein and elsewhere. Some of this was sent to Mr. Burrows for analysis. He was, however, not able to get a sample which he considers represents a single mineral. From one specimen sent to him by the writer he obtained the following percentages:

	Per cent.
Silver	57.40
Sulphur	15.94
Antimony	7.92
Iron	3.88
Arsenic	.52

Mr. Burrows afterwards analyzed other samples but with unsatisfactory results. For instance, he found the following percentages of silver: 47.24, 47.38, 64.29, 62.56, 63. He also proved the presence of lead in samples examined later. In one case he got 9 per cent. of lead, and in another only about 1.8. He found these samples to show considerable free silver, which no doubt accounts for the varying percentages of this metal, and that the mineral did not look the same in all parts, some of it being of a dull lustre and other parts bright.

TETRAHEDRITE

Mr. Burrows found a specimen of the tetrahedrite, which occurs massive, to possess the following composition:

	Per cent.
Copper	36.04
Sulphur	22.86
Antimony	21.86
Zinc	8.14
Iron	9.84
Cobalt	none
Nickel	none
Lead	not det.
Total	98.74

Tetrahedrite has been found in most of the mines at Cobalt.

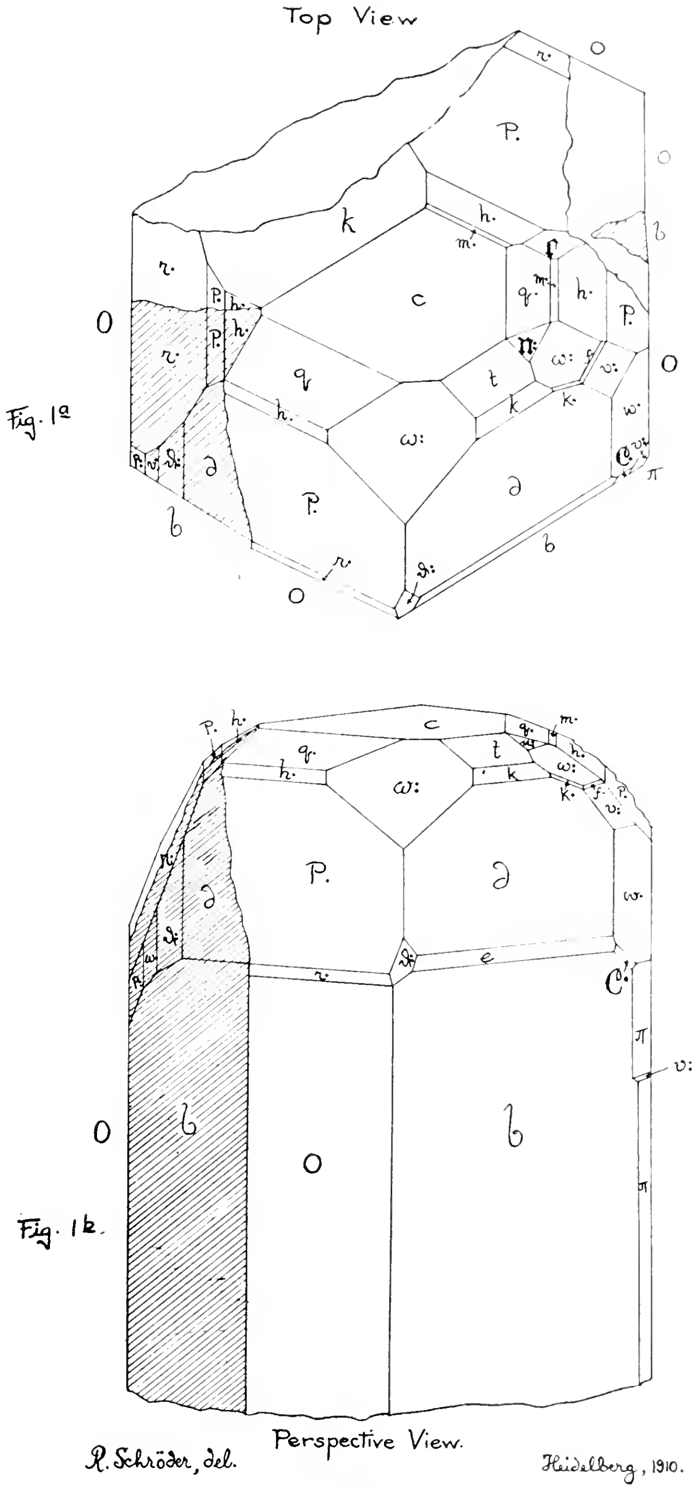


Fig. 17—Stephanite Crystal.

Sulphobismuthites

MATILDITE

A sample from the Nipissing mine, that appeared to be matildite, was submitted to Mr. N. L. Turner for analysis. In the following table, No. 1 gives the result of the analysis, and No. 2 is the theoretical composition of matildite.

	(1)	(2)
Silver	22.28	28.40
Sulphur	14.12	16.90
Bismuth	63.25	54.70
Total	99.65	100.00

Commenting upon the sample, Mr. Turner said: "Owing to the presence of native bismuth, it was impossible to prepare a pure sample. Consequently, the sample shows an excess of bismuth. A small quantity of arsenic was also present. The bismuth was completely surrounded with the other mineral."

Theoretically, in matildite the 22.28 parts of silver require 13.25 of sulphur. This shows that matildite is in all probability present in the sample analyzed.

EMPLECTITE

This mineral, to which reference is made on a preceding page, has been found only at the Floyd mine, to the west of Cobalt, near Sharp lake.

Phosphates

APATITE

Prof. Wm. Nicol found this mineral at the Columbus mine. He says it occurs in small, prismatic crystals, yellowish in color, without terminal planes. The crystals are about one-fourth to one-sixteenth of an inch in length. They were found in the decomposed matter in the druses in the rock associated with loose cobaltite crystals.

Veinstones

QUARTZ

This mineral is found rarely in the characteristic veins at Cobalt.

BARITE and FLUORITE

Barite and fluorite are characteristic veinstones in cobalt-silver deposits similar to those of Cobalt, *e.g.*, in the silver area near Port Arthur, Ont., and in well known veins of Germany and Austria. The former mineral has not been recognized by the writer in the veins at Cobalt proper, but occurs in the Cragg vein at Elk lake and in one or two other veins in the outlying areas. Both barite and fluorite are found with silver ore in veins in the township of Langmuir, southeast of Porcupine.

CALCITE and DOLOMITE

While the carbonate most characteristic of the veins is white in color, there is also a pink or reddish variety which may be said to occur more commonly in the deeper workings and to be associated with ore that carries little or no silver. In other words, the white variety, calcite, is associated with the richer ore, while the red variety, dolomite, is frequently met with when the values are disappearing. This relation does not always hold, and by solution and redeposition, no doubt carbonates of varying composition have been formed in the veins. The pink variety appears to be the older and the white the younger. The following are results of analyses of samples of the white or grey veinstones:

	1	2	3
Calcium carbonate	99.46	88.82	81.31
Magnesium carbonate	....	9.09	12.42
Iron and alumina	.12	1.70	5.73
Insoluble residue	....	0.45	0.52
Total	99.58	100.06	99.98

The sample represented by No. 1 came from the vein at the Violet mine in the diabase. It was taken by the writer and analyzed by Mr. Burrows. The absence of magnesium is noteworthy. Sample No. 2 came from vein 64 of the Nipissing, and No. 3 from the Crown Reserve mine. The last mentioned sample contained native silver, and the analysis was recalculated, discarding the results obtained for the silver.

Manganiferous Carbonate

The following table contains the results of analyses of the so-called "pink calcite" or dolomite from three mines. The anlyses were made by Mr. N. L. Turner, who says that the pink color is due, in all probability, to manganese, each sample showing distinct traces of this metal. The mineral can therefore be called manganiferous dolomite. It is interesting to know that a similar pink dolomite was found with the ores of Silver Islet and in other silver veins in the Port Arthur area. Ingall says: "Other salient features were the pink and cream-colored dolomitic spar, which so frequently formed a characteristic and prominent constituent of the gangue of the rich ore," and further: "Among these are the gangue minerals, calcite, quartz and dolomite, the latter varying in color from cream to pink according to the amount of manganese contained. . . . rhodochrosite is said to have been found."[15]

	1	2	3	4
Calcium carbonate	55.05	59.65	62.68	77.80
Magnesium carbonate	36.63	30.98	32.89	15.67
Manganese carbonate	.68	.25	.46	.88

1 Temiskaming mine, 3rd level. 2. O'Brien mine. 3. O'Brien mine. 4. Hargrave mine.

Since normal dolomite contains 54.35 per cent. of calcium carbonate and 45.65 of magnesium carbonate, and all the above analyses contain a higher percentage of calcium carbonate, the mineral is more properly called a manganiferous calcium-magnesium carbonate than a dolomite.

ARAGONITE

Dr. T. L. Walker kindly gave me the following note on the occurrence of aragonite at the Cobalt Lake mine:

"This mineral was observed on some specimens of the ore from the Cobalt Lake mine presented by the manager of the mine to Dr. A. P. Coleman, who gave me the material to examine. The chief part of the gangue is calcite, with a considerable amount of fine wire silver. The central part of the vein is drusy, the cavities being lined with wire silver, calcite crystals and fine radiating masses of delicate white crystals. These radiating masses of aragonite are not transparent but rather porcelainic in appearance. An examination showed that the mineral dissolves in hydrochloric acid, and has a specific gravity of about 2.90. Examined under the microscope the small crystals are transparent and extinguish parallel to the cross hairs. Crystallographically the mineral occurs in very slender acicular forms such as have been frequently observed for aragonite. The crystals are not suited for detailed measurements."

15. E. D. Ingall, An. Report, Geo. Sur. Can. Part H., 1887.

Bureau of Mines Specimens

Among the specimens secured from time to time by the Bureau of Mines for its collection, illustrative of the ores and rocks of Cobalt, three or four are worthy of special mention:

Trethewey Mine.—Through the courtesy of Mr. W. G. Trethewey, in the early years of Cobalt, a sample was obtained of the richer ore from his vein on location J B 7, since known as the Trethewey mine. This sample weighs 79 lb. Its length is 2 ft., average width about 8 inches, and average thickness $1\frac{1}{2}$ to 2 inches. Drillings, obtained by boring into the sample, show it to have the following composition. The calcium and magnesium carbonate represent the veinstone. The cobalt and nickel exist as arsenides, and the silver is essentially in the metallic form. Some of the iron shown in the analysis may have come from the drill.

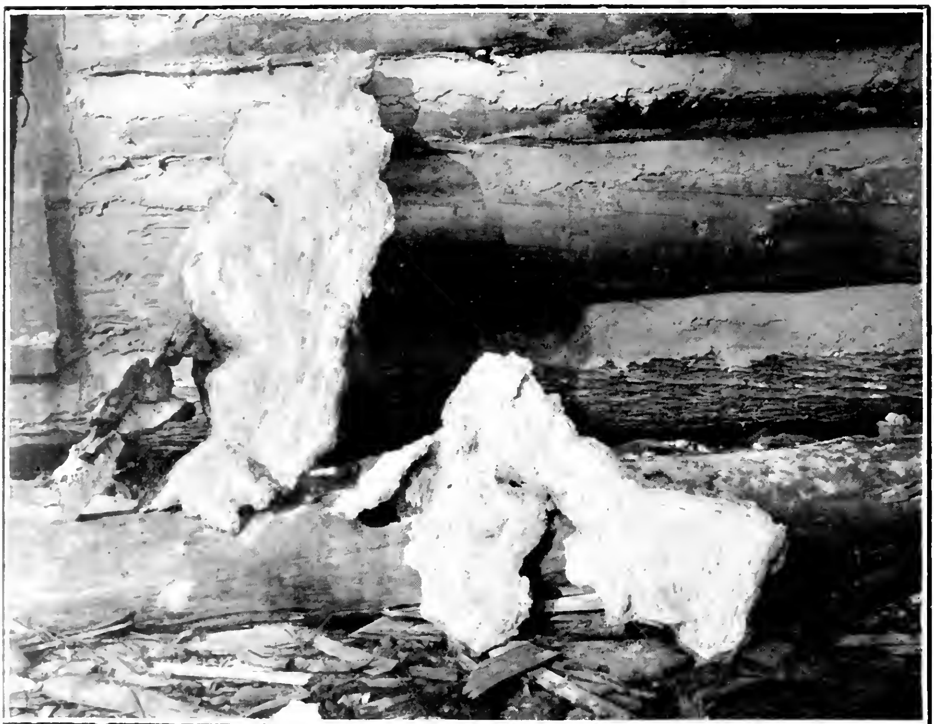


Fig. 18. Slabs of silver from the Trethewey Mine, location J B 7. The slab standing upright is the 79-pound specimen referred to in the text.

	Per cent.
Silver	66.67
Cobalt	2.15
Nickel	.41
Iron	1.60
Arsenic	7.03
Antimony	9.67
Sulphur	.22
Calcium carbonate	6.72
Magnesium carbonate	1.23
Insoluble	3.29

The value of the silver in this 79-lb. sample, at 54 cents an ounce Troy, is $410.

Crown Reserve Mine.—The specimen from this mine in the collection consists of a block of ore about 2 feet in diameter, weighing 1,259 lb. The fine silver content was determined by specific gravity to be 2,454 Troy ounces. The value of the specimen at

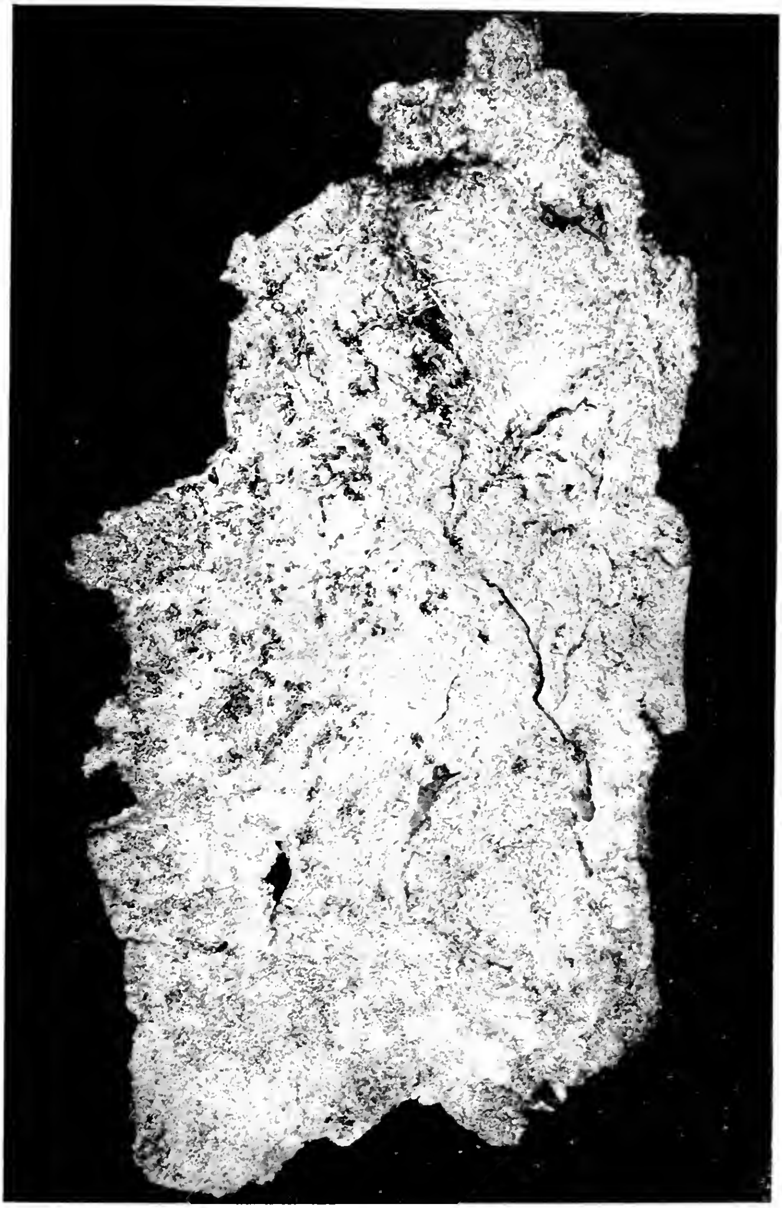


Fig. 19.—Coniagas Sample.

the time of purchase, October, 1908, silver at 51.25 cents an ounce, was $1,257.85. The ore consists essentially of native silver and calcite, together with a small included block of Cobalt slate-like greywacké. The specimen shows the vein at the point from which it was taken to have had a width of over 2 feet, which is large for a Cobalt vein. The specific gravity is 3.84.

Gem Claim.—What may be called a somewhat irregular slab of ore, 5 feet in length by 2 feet in width and about 1 foot thick, was found in the loose, glacial deposits when prospecting on this claim. It weighs 1,640 lb. and contains, by specific gravity determination, 9,715 Troy ounces of fine silver. At the time of purchase, January, 1910, the value of the specimen was approximately $5,000, silver then being worth 52.25 cents an ounce.

While the Trethewey and Crown Reserve specimens are of fresh ore blasted out of the vein, the Gem specimen represents material weathered out and transported by natural agencies. The specimen contains considerable rock, Cobalt greywacké, and calcite. Its surface is well coated with the delicately colored cobalt bloom. The metallic constituents are native silver and dyscrasite. The ore resembles some of that of the Kerr Lake mine, which lies 3,000 feet to the east of north of the Gem claim. It would appear that the specimen was carried from what is now this mine by glacial agency. It may be added that numerous nuggets and chunks of cobalt-silver ore have been found in trenching in the area to the south of the productive Cobalt area.

Coniagas.—One of the most beautiful specimens in the Bureau of Mines collection is a slab or sheet of essentially native silver, approximately 32 inches long, 14 inches wide, and one-half to 1 inch thick. This specimen weighs 37 lb. avoirdupois and at the time of its purchase, November, 1911, was valued at $350. The sample came from the 150-foot level of vein No. 12, Coniagas mine. (Fig. 19.)

Exhibit of Cobalt-Silver Ores

Through the Bureau of Mines, arrangements were made for securing a collection of the cobalt-silver ores for exhibition at the Louisiana Purchase Exposition, held at St. Louis in 1904. These were obtained at the request of Mr. William Hutchison, Dominion Exhibition Commissioner, who has since purchased the samples exhibited, with the object of keeping them as a permanent exhibit. They were afterwards sent to the Liege Exhibition, Belgium, and elsewhere.

The following notes given to the writer by Mr. W. E. H. Carter, late Provincial Inspector of Mines, show the composition and character of the exhibit. While the exhibit was at St. Louis it was sampled by Mr. Carter, who has this to say of the various specimens: "The niccolite contains silver not only disseminated but in pure stringers and nuggets as well. These nuggets and stringers were not included in the sample taken for analysis, but should be considered as adding materially to the value of the ore represented by my sample.

"I. Cobalt-Silver Ore, Sample from R L 404:

(*a*) 50 lb. decomposed material with silver, containing by estimate 30 p. c. silver, which amounts to 218 oz., and at 55c. per oz....	$119 90
(*a*) 14 pieces, wall rock with silver; (*b*) 61 pieces cobalt ore .... } 75 pieces weighing 6,510 lb.	
This 6,510 lb. contains by assay:	
Silver, 2.58 oz. per ton, at 55c.	$4 62
Cobalt, 18.04 p. c.—1,174.4 lb., at 65c.	763 36
Nickel, 5.52 p. c.—359.35 lb., at 15c.	53 90
Arsenic, 39.56 p. c.—791.2 lb., at 1c.	7 91
Total value of sample	$949 69

(*a*) From Little Silver vein, southwest corner of location R L 404.
(*b*) From Cobalt Hill vein, in northwest corner of the same location.

"II. Niccolite-Silver Ore, from La Rose mine, Location J S 14 on map:
Containing by assay:

	Value per ton.
Silver, 7.944 p. c.—2,317 oz. per ton, at 55c.	$1,274 35
Cobalt, 8.93 p. c.—178.6 lb., at 65c.	116 09
Nickel, 15.67 p. c.—313.4 lb., at 15c.	47 01
Arsenic, 39.56 p. c.—791.2 lb., at 1c.	7 91
Total per ton	$1,445 36
There are about three tons in the sample	4,336 08

"III. Trethewey's Cobalt-Silver Ore, Location J B 7 on map:

145 lb. in all. Of this, 15 lb. is by estimate pure silver—212 oz. and at 55c.	$116 60
And 130 lb. is cobalt ore containing silver, and valued at $1.50 per lb.	195 00
Total value	$311 60

"In valuing the above ores I have taken the prices paid by the dealers at New York for the crude ore, which are as follows for the several metals:

Silver	Market value.
Cobalt	65c. per lb.
Nickel	15c. per lb.
Arsenic	1c. per lb.

The value of these samples of ore, which are to be kept for exhibition purposes, is approximately as follows:

(1) Sample of cobalt-silver ore from R L 404, weight 6,560 lb., value	$949 69
(2) Niccolite-silver ore from La Rose mine, exact weight not given, but if it is three tons, as stated, the value of the sample is	4,336 08
(3) Trethewey cobalt-silver ore, 145 lb. in all, value	311 60
Total value of collection	$5,597 37

The cobalt is contained essentially in the mineral smaltite, which is a diarsenide of this metal. Most of the nickel in the samples occurs as the arsenide, niccolite, but some of the metal is in the diarsenide form, chloanthite. The greater part of the silver is in the native form, although the sulphide, argentite, the sulph-antimonide, pyrargyrite, and other compounds of the metal are found in the deposits.

Character of Cobalt Ores

To the foregoing description of the minerals of the veins and of specimens of ore a few notes may be added concerning shipments. This will bring out still more clearly the great richness of the vein contents.

Additional notes on the richness of the ores, and the cost of producing silver, will be found on a following page.

1904.

The character of the ore produced in 1904, when mining began, will be seen from the following:

Silver, ounces	206,875	$111,887 00
Cobalt, tons	16	19,960 00
Nickel, tons	14	3,467 00
Arsenic, tons	72	904 00
Total		$136,218 00

Ore shipped, 158 tons; value per ton, $862.13.

This gives the following average percentage of the four metals in the ore shipped.

Silver	5.34	per cent. or 1,309.33 ounces per ton
Cobalt	10.21	" "
Nickel	8.86	" "
Arsenic	45.56	" "

1905.

The production for the first quarter year ending March 31st, 1905, during which shipments were made, was 354.05 tons of ore, valued at $293,552. The ore thus averaged $829 a ton. The average percentage of the metals in the ore was as follows:

	Per cent.
Silver	4.802
Cobalt	8.264
Nickel	4.739
Arsenic	34.606

The 4.802 per cent. of silver represents 1,406.27 ounces a ton. The cobalt, nickel and arsenic in one carload are not included, no returns having been made.

During the second quarter, March 31st to June 30th, 1905, the shipments were 537 tons, valued at $394,552, or an average of $734 a ton.

The average percentage of the metals in the ore for this quarter was:

	Per cent.
Silver	4.158
Cobalt	6.890
Nickel	3.091
Arsenic	30.912

The metals in the ore were sold at approximately the following prices: Silver, 55 to 60 cents an oz. Troy for 90 per cent. of the contents; cobalt, 65 cents; nickel, 12 to 15 cents, and arsenic about 1 cent a pound.

During the first quarter of the year there were four companies or individuals who made shipments. During the second quarter small shipments were made from one or two other properties. During the second half of 1905 there were seventeen shippers.

During the second half of the year, owing to there being no plants in America adapted to extracting all the constituents of the ores, the mine owners received, in some cases, no pay for the cobalt, nickel and arsenic contents, the purchasers allowing for the silver only. For this reason the statistics of production received by the Bureau of Mines are incomplete, complete analyses not having been made of some shipments. In compiling the following table the average of the cobalt, nickel and arsenic contents in the shipments analyzed has been taken, and proportionate percentages, based on the silver, in the shipments of which complete analyses were made, has been added to those which were incompletely analyzed.

Owing to their receiving nothing for some of the metallic contents of the ores, if sold during the latter half of the year, the producers had stored at their mines on December 31st, 1905, the end of the year represented by the statistics, a considerable quantity of ore. In two or three cases the quantity in storage represented a value of $100,000 or more. The following table, therefore, does not represent the total production for 1905, but merely the shipments:

	Quantity.	Value.
Tons of ore shipped	2,144	
Silver, ounces	2,441,421	$1,355,306
Cobalt, tons	118	100,000
Nickel, tons	75	10,525
Arsenic, tons	549	2,693

The 2,144 tons of ore shipped during the year had therefore a percentage composition of:

Silver	3.90
Cobalt	5.50
Nickel	3.49
Arsenic	25.60

A percentage of silver of 3.90 represents 1,138.72 ounces a ton, or at 64 cents an ounce, the then price of silver, a value of $728.78 a ton of ore throughout the year. It is needless to say that the average value of the ore shipped from few mining camps can equal this. The average value of the total metallic contents per ton of ore shipped throughout the year 1905, at the prices received, was $684.94. It should be noted that most of the ore mined during the year came from near the surface. Hence the percentage of cobalt, nickel and arsenic is lower than when greater depth is reached, the metals being leached out by surface agencies.

The ore shipped till near the end of 1907 was sorted by hand. Since then extensive concentrating plants have been erected. These plants are described in other reports.[16]

Production of Cobalt Mines, 1904-1912

The following table summarizes the production of the Cobalt and adjacent areas.

Year	Ore shipped	Nickel		Cobalt		Arsenic		Silver		Total value
	Tons	Tons	Value	Tons	Value	Tons	Value	Ounces	Value	
			$		$		$		$	$
1904	158	14	3,467	16	19,960	72	903	206,875	111,887	136,217
1905	2,144	75	10,000	118	100,000	549	2,693	2,451,356	1,360,503	1,473,196
1906	5,335	160	....	321	80,701	1,440	15,858	5,401,766	3,667,551	3,764,113
1907	14,788	370	1,174	739	104,426	2,958	40,104	10,023,311	6,155,391	6,301,095
1908	25,624	612	....	1,224	111,118	3,672	40,373	19,437,875	9,133,378	9,284,869
1909	30,677	766	....	1,533	94,965	1,294	61,039	25,897,825	12,461,576	12,617,580
1910	34,282	504	....	1,098	54,699	1,897	70,709	30,645,181	15,478,047	15,603,455
1911	26,653	392	....	852	170,890	3,806	74,609	31,507,791	15,953,847	16,199,346
1912	29,173*	....	....	515	317,165**	1,964***	79,297	30,243,859	17,408,935	17,805,397
Total								155,815,839	81,731,115	83,185,268

The average value of the ore shipped during the first three years was $704 per ton. For the first year, when only very rich material left the camp, the ore averaged $862 per ton; in 1905, when a large quantity of low-grade gravel was included in the shipments, it fell to $687 per ton; while in 1906, the average went up to $705 per ton, practically identical with the average for the whole period. A considerable proportion of the consignments in 1906 was also of second or third class quality, but on the other haud there were many carloads of unusual richness. The percentage of low grade ore shipped in 1907 showed an increase. Concentration plants erected since then have brought about the treatment of most of the low-grade ore at Cobalt.

16 Part I. of the annual report of the Bureau of Mines, and Mr. A. A. Cole's annual reports to the T. N. O. Railway Commission.

*Does not include ore refined at Cobalt. **Cobalt oxide, etc. ***Refined.

Mines, Concentrating and Refining Plants and Water Power

The working mines of Cobalt and adjacent silver areas are described in Part I of the Annual Reports of the Ontario Bureau of Mines, and in the Annual Reports of Mr. A. A. Cole to the Temiskaming and Northern Ontario Railway Commission. Descriptions of the concentrating, refining and water power plants are to be found in the same reports and in the technical press.

The tendency towards final treatment of the ore in the camp is manifested in the increased shipments of bullion, consignments of which amounted to 5,071,897 ounces in 1912 as against 3,132,976 ounces in 1911. The Nipissing and Buffalo mines are now equipped for reducing their entire output to merchantable bars on the spot. Nevertheless, the tonnage of ore and concentrates shipped to outside points in 1912 was larger than in 1911, the respective quantities being 17,959 tons ore, and 11,214 tons concentrates, as compared with 17,278 tons ore, and 9,375 tons of concentrates in 1911. The year of largest shipments was 1910, when 27,437 tons ore and 6,845 tons concentrates left the camp.

The largest producers during 1912 were as follows:

	Silver.	
Nipissing	4,680,670	ounces.
Coniagas	3,703,942	"
La Rose	2,920,344	"
Crown Reserve	2,714,765	"
McKinley-Darragh-Savage	2,694,560	"
Kerr Lake	1,895,309	"
Buffalo	1,890,150	"
Cobalt Townsite	1,505,396	"
Temiskaming	1,217,994	"
O'Brien	1,091,631	"

In Gowganda, in 1912, three mines—Miller Lake-O'Brien, Milleret and Mann—produced in all 549,976 ounces, and in South Lorrain one—Wettlaufer-Lorrain—834,119 ounces. Casey township has also become an important producer.

In 1912, as in previous years, the larger proportion of the high-grade ore and concentrates produced at Cobalt was treated in refineries situated in Ontario, the principal works being those at Copper Cliff, Deloro, Thorold and Orillia. At Deloro and Thorold, also at a small refinery opened during the year at North Bay, the oxides of cobalt and nickel are produced and large shipments made, both of refined cobalt oxide and of the mixed oxides of cobalt and nickel, to the United States and European markets. Another by-product turned out by the refineries is white arsenic, of which nearly four million pounds were made during the year. The Cobalt plant at Copper Cliff is now permanently closed.

There was paid out in dividends by silver mining companies in the Cobalt camp over seven million dollars in 1912. The total distribution of profits since the beginning of the camp has been close upon 41 millions of dollars on a gross aggregate return for sales of silver of $81,777,260.

Dividends Declared and Paid by Silver-Cobalt Mining Companies to end of 1912.

Name of Company.	Date of Incorporation.	Authorized Capital.	Capital Stock issued.	Par value per share.	Amount of Dividends and Bonuses declared to end of 1911.	Amount of Dividends and Bonuses declared during 1912.	Total of Dividends and Bonuses declared to Dec. 31, 1912.	Last Dividend or Bonus. Date declared.	Last Dividend or Bonus. Rate per cent.
		$	$	$	$ c.	$ c.	$ c.		
Beaver Consolidated Mines, Limited	Mar. 5, 1907	2,000,000	2,000,000	1.00	170,000 00	180,000 00	350,000 00	Dec. 21, 1912	3
Buffalo Mines, Limited	April 27, 1906	1,000,000	1,000,000	1.00	1,377,000 00	500,000 00	1,877,000 00	Dec. 4, 1912	26
City of Cobalt Mining Company, Limited	Oct. 5, 1906 / Jan. 7, 1909	500,000 / 1,500,000	1,500,000	1.00	139,312 42	....	139,312 42	April 15, 1909	3
Cobalt Central Mines Company	Dec. 13, 1906	5,000,000	5,000,000	1.00	192,845 00	....	192,845 00	Aug. 25, 1909	1
Cobalt Lake Mining Company, Limited	Dec. 22, 1906	†5,000,000	3,929,166	1.00	....	75,000 00	75,000 00	Nov. 26, 1912	2½
Cobalt Silver Queen, Limited	April 1, 1906	1,500,000	1,500,000	1.00	315,000 00	....	315,000 00	Dec. 31, 1908	3
Cobalt Townsite Mining Co., Limited	May 6, 1906	100,000	45,011	1.00	125,000 00	346,000 00	471,000 00	Nov. 1912	324
Coniagas Mines, Limited	Nov. 21, 1906	4,000,000	4,000,000	5.00	2,810,000 00	1,110,000 00	1,280,000 00	Oct. 11, 1912	9
Crown Reserve Mining Company, Limited	Jan. 16, 1907	2,000,000	1,999,957	1.00	3,711,509 40	1,061,288 40	4,775,797 80	Dec. 15, 1912	5
Foster Cobalt Mining Company, Limited	Feb. 11, 1906	1,000,000	915,588	1.00	45,000 00	....	45,000 00	Jan. 1, 1907	5
Kerr Lake Mining Company	Aug. 9, 1905	3,000,000	3,000,000	5.00	3,940,000 00	670,000 00	4,610,000 00	Oct. 8, 1912	7
La Rose Consolidated Mines Company	Feb. 21, 1907	7,500,000	7,193,135	5.00	2,672,000 00	1,000,546 84	3,672,546 84*	Dec. 16, 1912	5
McKinley-Darragh-Savage Mines of Cobalt, Limited	April 9, 1906	2,500,000	2,247,692	1.00	2,156,721 38	1,123,846 00	3,280,637 38	Nov. 1, 1912	20
Nipissing Mines Company	Dec. 16, 1904	6,000,000	6,000,000	5.00	8,325,797 25	1,842,500 00	10,168,297 25	Dec. 9, 1912	7½
Right of Way Mining Company, Limited	July 13, 1906	500,000	500,000	1.00	321,643 93	....	321,643 93	....	....
The Right of Way Mines, Limited	Sept. 11, 1909	2,000,000	1,685,500	1.00	202,260 00	....	202,260 00	Dec. 2, 1911	2
Temiskaming and Hudson Bay Mining Company, Limited	July 29, 1903	25,000	7,761	1.00	1,521,156 00	209,547 00	1,730,703 00	....	300
The Hudson Bay Mines, Limited	July 16, 1909	3,500,000	3,200,050	5.00	394,903 42	192,003 00	586,906 42	Sept. 20, 1912	3
Temiskaming Mining Company, Limited	Nov. 16, 1906 / Jan. 1, 1908	2,500,000	2,500,000	1.00	1,009,156 00	300,000 00	1,309,156 00	Dec. 31, 1912	3
Trethewey Silver Cobalt Mine, Limited	May 30, 1906 / June 1, 1911	1,000,000 / 2,000,000	1,000,000	1.00	761,998 50	100,000 00	861,998 50	June 1, 1912	10
Wettlaufer Lorrain Silver Mines, Limited	Nov. 30, 1908	1,500,000	1,416,590	1.00	283,318 00	283,318 00	566,636 00	Nov. 25, 1912	5
Casey Cobalt**	....	....	....	....	....	....	....	....	....
Seneca-Superior**	....	....	....	....	....	....	....	....	....
Total						9,321,019 21	39,821,740 51	....	....

*In addition to profits to owners previous to May 31, 1908, amounting to $1,201,862.72. **Paid dividend, 1913.
†Reduced by shares purchased for cancellation to $1,070,834. Dividends of closely controlled or privately owned properties such as O'Brien, Drummond, Miller Lake O'Brien and Millerett are not made public.

High and Low Prices of Stocks of Cobalt-Silver Mines

The following table of the annual high and low prices of the stocks of the cobalt-silver mines has been compiled from various sources. Information has been kindly furnished by brokers and by the financial editors of some of the newspapers. While the prices given in the table vary in a few cases from those published in certain lists, they are as nearly correct as it seemed possible to make them. Data for the individual years 1906 and 1907 being incomplete, the highest and lowest prices to the end of 1907 are given. The records for 1908 and succeeding years are more complete.

The capitalization of the companies mentioned is given in the preceding table of dividends. Stock in many other companies was sold, but the table is confined to those which are of the most interest.

Name of Company.	To end of 1907		1908		1909		1910		1911		1912	
	High	Low	High	Low	High	Low	High	Low	High	Low	High	Low
Beaver or Beaver Consolidated Mines, Limited	.88	.20	.66½	.24	.44	.09½	.38½	.18	.52	.25½	.50	.39
Buffalo Mines, Limited	5.00	.80	3.62½	2.15	3.60	2.50	2.50	1.96	2.30	1.40	2.50	1.20
City of Cobalt Mining Company, Limited	2.83	2.38	2.80	1.75	2.81	.33	.55½	.19½	.21	.05½	.36½	.07
Cobalt Central Mines Company	.76	.16½	.74	.21	.58½	.24	.23	.06	.10	.01	.01	.0½
Cobalt Lake Mining Company, Limited	.85	.09	.25½	.10	.19½	.11½	.29¾	.12¼	.29¾	.12¾	.59	.17
Cobalt Silver Queen, Limited	3.50	.62	1.28	.721	1.00	.19	.23	.04½	.10	.02	.07½	0.03
Coniagas Mines, Limited	8.50	3.30	7.20	3.90	7.00	5.25	6.00	4.19	7.60	6.00	8.25	6.70
Crown Reserve Mining Company, Limited	3.10	.20	2.88	.38	5.99	2.63	4.10	2.52	3.60	2.38	3.60	2.00
Foster Cobalt Mining Company, Limited	4.37	.35	.89	.38	.70½	.22	.31	.04	.07	.02½	.19½	.03
Kerr Lake Mining Company, Limited	7.80	2.55	7.80	2.60	9.43	7.60	11.00	6.00	7.75	2.70	3.15	2.55
La Rose Consolidated Mines Company	....	....	7.12½	6.08	8.47	4.20	5.02	3.30	5.00	3.70	4.01	2.10
McKinley Darragh Savage Mines of Cobalt, Ltd.	4.12	.64½	1.30	.64½	1.01	.84	1.40	.79½	1.88	1.29	2.20	1.60
Nipissing Mines Company	34.25	5.50	12.637	6.12	12.91	9.25	11.75	9.50	11.25	6.60	9.35	5.78
Right of Way Mining Company, Limited / The Right of Way Mines, Limited	10.50	1.00	4.00	3.65	3.70	1.30	.31	.20	.29¾	.04½	.13	.05
Temiskaming and Hudson Bay Mining Company, Limited / The Hudson Bay Mines, Limited	....	....	....	....	290.	148.	143.	98.	108.	80.	90.	63.
Temiskaming Mining Company, Limited	2.25	.26	2.00	.28½	1.79	.67	.98	.52	.92	.25½	.49	.30
Trethewey Silver Cobalt Mine, Limited	2.85	.46	1.80	.47	1.64	1.29	1.45	1.13½	1.22	.51	.77	.31
Wettlaufer Lorrain Silver Mines, Limited	....	....	....	....	....	....	1.42	.52	1.23	.75	.83	.23

Silver Production of the World*

(In fine ounces)

—	1911	1912**
Mexico	79,032,440	76,500,000
United States	60,399,400	62,369,903
Canada	32,740,748	31,931,710
Australasia	16,578,421	17,950,000
Other Countries	36,621,835	37,500,000
Total	225,372,844	226,251,013

*Eng. and Min. Journ., Jan. 11th, 1913. **Subject to revision.

Production of Silver in World since 1871

Annual Average for Period

Period	Fine Ounces	Coining Value
1871–75	63,317,014	$81,864,000
1876–80	78,775,602	101,851,000
1881–85	92,003,944	118,955,000
1886–90	108,911,431	140,815,000
1891–95	157,581,331	203,742,000
1896–1900	165,693,304	214,229,700
1901	173,011,283	223,691,300
1902	162,763,483	210,441,900
1903	167,689,322	216,810,300
1904	164,195,266	212,292,900
1905	172,317,688	222,794,500
1906	165,054,497	213,403,800
1907	184,206,984	238,166,600
1908	203,131,404	262,634,500
1909	210,453,431	272,101,400
1910	222,879,362	288,167,300
1911	225,372,844	
1912	226,251,015*	

* Subject to revision.

United States Silver Production

(Fine Ounces)

—	1911	1912*
Alabama	200	237
Alaska	408,300	516,224
Arizona	3,228,900	3,456,989
California	1,270,900	1,255,192
Colorado	7,331,200	8,350,316
Georgia	600	65
Idaho	8,184,900	7,703,721
Illinois	4,000	3,740
Maryland and Pennsylvania	100	201
Michigan	507,700	543,360
Missouri	49,100	25,311
Montana	12,163,900	12,338,589
Nevada	13,185,900	13,042,118
New Mexico	1,341,400	1,251,412
North Carolina	1,000	3,783
Oregon	44,800	79,896
South Carolina	....	40
South Dakota	200,300	200,796
Tennessee	107,000	109,773
Texas	444,200	420,994
Utah	11,630,600	12,795,072
Virginia	200	7,974
Washington	230,300	258,152
Wyoming	700	298
Total Continental U.S.	60,395,917	62,364,253
Philippine Islands	3,000	5,650
Porto Rico	100	....
Total	60,399,400	62,369,903
Total Value	$32,195,296	$37,942,773

* Subject to revision.

Monthly Average Price of Silver

Month.	New York.			London.		
	1910	1911	1912	1910	1911	1912
January	52,375	53,795	56,260	24,154	24,865	25,887
February	51,534	52,222	59,043	23,794	24,081	27,190
March	51,454	52,745	58,375	23,690	24,324	26,875
April	53,221	53,325	59,207	24,483	24,595	27,284
May	53,870	53,308	60,880	24,797	24,583	28,038
June	53,462	53,043	61,290	24,651	24,486	28,215
July	54,150	52,630	60,654	25,034	24,286	27,919
August	52,912	52,171	61,606	24,428	24,082	28,375
September	53,295	52,440	63,078	24,567	24,209	29,088
October	55,490	53,340	63,471	25,596	24,594	29,299
November	55,635	55,719	62,792	25,680	25,649	29,012
December	54,428	54,905	63,365	25,160	25,349	29,320
Year	53,486	53,304	60,835	24,670	24,592	28,842

New York quotations, cents per ounce Troy, fine silver; London, pence per ounce, sterling silver, 0.925 fine. The table is taken from Eng. and Min. Jr., Jan. 11th, 1913.

Coined silver in the United States on January 1, 1913, is estimated as follows: Standard dollars, \$565,481,020; subsidiary coins, \$174,538,163; total, \$740,029,183.

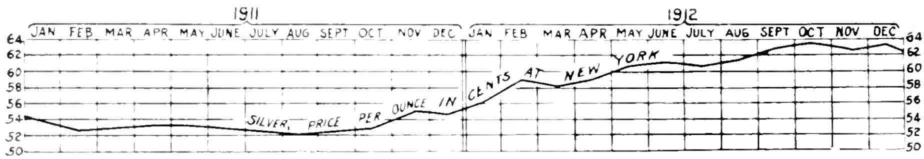


Fig. 20, Monthly average price of silver, 1911 and 1912.

Average Price of Bar Silver in London since 1833

(The equivalent in United States Gold Coin of one ounce 1,000 fine.)

	Dollars.		Dollars
1833	1.297	1859	1.3600
1834	1.313	1860	1.3520
1835	1.308	1861	1.3330
1836	1.315	1862	1.3460
1837	1.305	1863	1.3450
1838	1.304	1864	1.3450
1839	1.323	1865	1.3380
1840	1.323	1866	1.3390
1841	1.316	1867	1.3280
1842	1.303	1868	1.3260
1843	1.297	1869	1.3250
1844	1.304	1870	1.3280
1845	1.982	1871	1.3260
1846	1.300	1872	1.3220
1847	1.308	1873	1.29769
1848	1.304	1874	1.27883
1849	1.309	1875	1.24233
1850	1.316	1876	1.16414
1851	1.337	1877	1.20189
1852	1.326	1878	1.15358
1853	1.348	1879	1.12392
1854	1.348	1880	1.14507
1855	1.344	1881	1.13229
1856	1.344	1882	1.13562
1857	1.353	1883	1.10874
1858	1.344	1884	1.11068

	Dollars		Dollars
1885	1.66510	1899	.60154
1886	.99467	1900	.62007
1887	.97946	1901	.59595
1888	.93974	1902	.52795
1889	.93511	1903	.54257
1890	1.04634	1904	.57876
1891	.98800	1905	.61027
1892	.87145	1906	.67689
1893	.78030	1907	.66152
1894	.63479	1908	.53490
1895	.65466	1909	.52016
1896	.67565	1910	.54077
1897	.60438	1911	.53304
1898	.59010	1912	.60835

Cobalt

The production of cobalt from the mines at Cobalt and surrounding areas much exceeds the consumption of the finished oxide, and new uses must be found for the metal or its compounds before the industry can expand. The price of cobalt oxide is only about one-third what it was a few years ago. At present the principal use, as it has been for centuries, is in the making of pottery and glass. It is said that glass colored with cobalt has been found in the ruins of Troy and in the graves of the ancient Egyptians. An account of the early cobalt industry in Saxony will be found in an appendix to this report.

The world's consumption is estimated at 300 tons of cobalt oxide annually. Sufficient ore is produced at Cobalt to provide 1,500 tons or more annually.

The trade in cobalt oxide has been closely controlled. The price in 1912, according to the *Engineering and Mining Journal*, was held at 80 cents per lb. without change. An increase of 10 cents per lb. has been announced for 1913.

Continued successful experiments with cobalt as an alloy of tin or chromium to produce special metals for cutlery and other purposes, and with cobalt salts as paint driers, have been made.

Cobalt Oxide, Ore and Zaffer Imported into the United States for Consumption, 1901-11 in pounds.*

Years.	Quantity.	Value.
1901	71,969	$134,208
1902	79,984	151,115
1903	73,350	145,264
1904	42,354	86,925
1905	70,048	139,377
1906	41,084	83,167
1907	48,013	74,849
1908	219,098	17,077
1909	12,132	11,696
1910	14,935	6,352
1911	579,520	48,104

Arsenic, Production and Uses

The Ontario production of arsenic from the Cobalt mines is summarized on a preceding table, page 35.

With the withdrawal, in 1912, of the Canadian Copper Company from the treatment of Cobalt ores, the Deloro Mining and Reduction Company and the Coniagas Reduction Company are now the only producers of white arsenic in Canada.

*Min. Res. U.S., 1911, Part I., p. 959.

Not many years ago Deloro had the only plant for the production of white arsenic in North America, the ore then treated being the auriferous mispickel mined at the plant. Since then the industry has made marked progress in the United States, the producers now being the Anaconda Company, the American Smelting and Refining Company, and the United States Smelting Company. There is also a plant in Virginia. Moreover, some of the large sulphuric acid makers are said to be marketing arsenious sulphide derived as a by-product in refining acid.

There is no duty on arsenic and its compounds going into the United States.

The Compania de Penoles is the only producer in Mexico. The plant is worked on flue dust.

The Following Table gives the World's Production of Arsenic in Metric Tons:

Year	Canada (a)	Germany (b)	Italy (d)	Japan (a)	Portugal (d)	Spain (a)	United Kingdom (a)	United States (a)	France (d)
1909......	1.020	2.911	nil	8	1,420	506	2.911	914	2,381
1910......	1.363	3.066	nil	12	974	444	2.187	1,203	2,141
1911......	1.902	2.981	16	....	(c)	(c)	2.178	2,800	(c)
1912......	1,964	....	....	....	....	....	....	2,655	....

(*a*) White arsenic. The arsenic in the ores shipped from Cobalt during each of the three years, 1909-1911, was 4,294, 4,897, and 3,806 tons respectively. (*b*) Oxide, sulphide, etc.; (*c*) not yet available; (*d*) ore.

The annual production of the arsenical ores, orpiment and realgar, in China, is estimated at 600 tons.

Within the last few years there has been a great expansion in the manufacturing of arsenical products, especially insecticides.

The imports of white arsenic into the United States are given as 8,204,123 pounds in 1910, and 6,916,069 in 1911.

The price of arsenic materiallly increased during 1912. At the beginning of the year it was 1⅞ to 2 cents per lb. At the close it was about 4⅞ cents.

The uses for arsenical compounds are numerous and the market for them is increasing, especially in connection with agriculture. Much of the Canadian arsenic has been sold to plate glass manufacturers in the United States.

The following is a summary of the uses to which is put white oxide, the material produced at the Canadian refining plants.*

Arsenious oxide, or white arsenic, is used as an insecticide; in the preservation of furs and leather; also as a preservative of wood, where it prevents the fungus growth. The most important demand for arsenic is in the manufacture of Paris green, this product being employed as an insecticide. Arsenic is also extensively used as a fixing medium, or mordant, in connection with aniline dyes, and in printing of calico and wall-paper. Among the important colors in which arsenic is used are Scheele green, London purple, and in certain yellows, reds and grays. Arsenic is also used in the manufacture of glass and enamel; it also finds a small use in medicine. Arsenic soap is another familiar use. Realgar, which is an arsenic sulphide, burns with a bright white light and is used in the manufacture of pyrotechnics. Arsenic hardens lead and finds employment in this connection in the manufacture of shot.

*[illegible] Vol. XVII, p. 54.

United States Production and Imports of Arsenic, 1902-1911.*

Year.	Production of White Arsenic.		Imports. (a) White arsenic, metallic arsenic, and arsenic sulphides.		Imports. (a) Paris green and London purple.	
	Quantity.	Value.	Quantity.	Value.	Quantity.	Value.
	(short tons)	$	(short tons)	$	(short tons)	$
1902........	1,353	81,180	4,055	280,055	....	....
1903........	611	36,691	4,179	294,602	....	....
1904........	36	2,185	3,400	243,380	28,498	985
1905........	754	35,210	3,838	256,540	44,931	1,118
1906........	737	63,460	3,987	350,045	311,293	21,347
1907........	1,751	163,000	5,164	574,998	133,422	21,919
1908........	(b)	....	4,964	430,400	195,000	30,764
1909........	1,214	52,946	4,036	303,728	183,765	20,370
1910........	1,497	52,305	5,139	314,306	181,363	14,648
1911........	3,132	73,408	4,096	247,323	126,191	4,972

(a) Figures furnished by the Bureau of Statistics.

(b) There were only two producers of arsenic in the United States in 1908, so that the figures of production may not be given.

Bismuth

While native bismuth is found at times in considerable quantity, and the compounds of the metal to a lesser extent, in the cobalt-silver ores, the mining companies have received no pay for it. No bismuth refined from Cobalt ores has been reported as having come on the market.

The bismuth business of the world is in the hands of the European convention, which for many years has monopolized production. The convention's price during 1912 remained at 7s. 6d., London, which was the same as in 1911.**

Only in the United States is there any independent production of bismuth worth mentioning. Here, the United States Smelting and Refining Company produces a relatively small quantity out of the Betts process slimes. This American producer keeps its output within such limits as enable it to market all at a little under the convention's price, without inciting a trade war, which probably neither party wants. The quotation for bismuth in the United States in 1912 was $1.72 per lb. throughout the year.

In 1913 there will be a new producer, viz., the American Smelting and Refining Company, which is to refine the metal at its Omaha plant. Experiments are also said to have been made in the production of the metal at Chrome and Perth Amboy, N.J., but no sales were reported from these plants in 1912.

Imports for Consumption of Metallic Bismuth into the United States, 1904-11, inclusive, in pounds.***

Year.	Quantity.	Value.
1904...........................	185,905	$339,058
1905...........................	148,589	318,007
1906...........................	254,733	318,452
1907...........................	259,881	325,015
1908...........................	164,793	257,397
1909...........................	183,413	286,516
1910...........................	198,174	332,668
1911...........................	172,093	311,771

*Min. Res. U.S., 1911, Part II, p. 855. **Eng. and Min. Jour. Jan. 11th, 1913. ***Min. Res. U.S., 1911, Part I, p. 976.

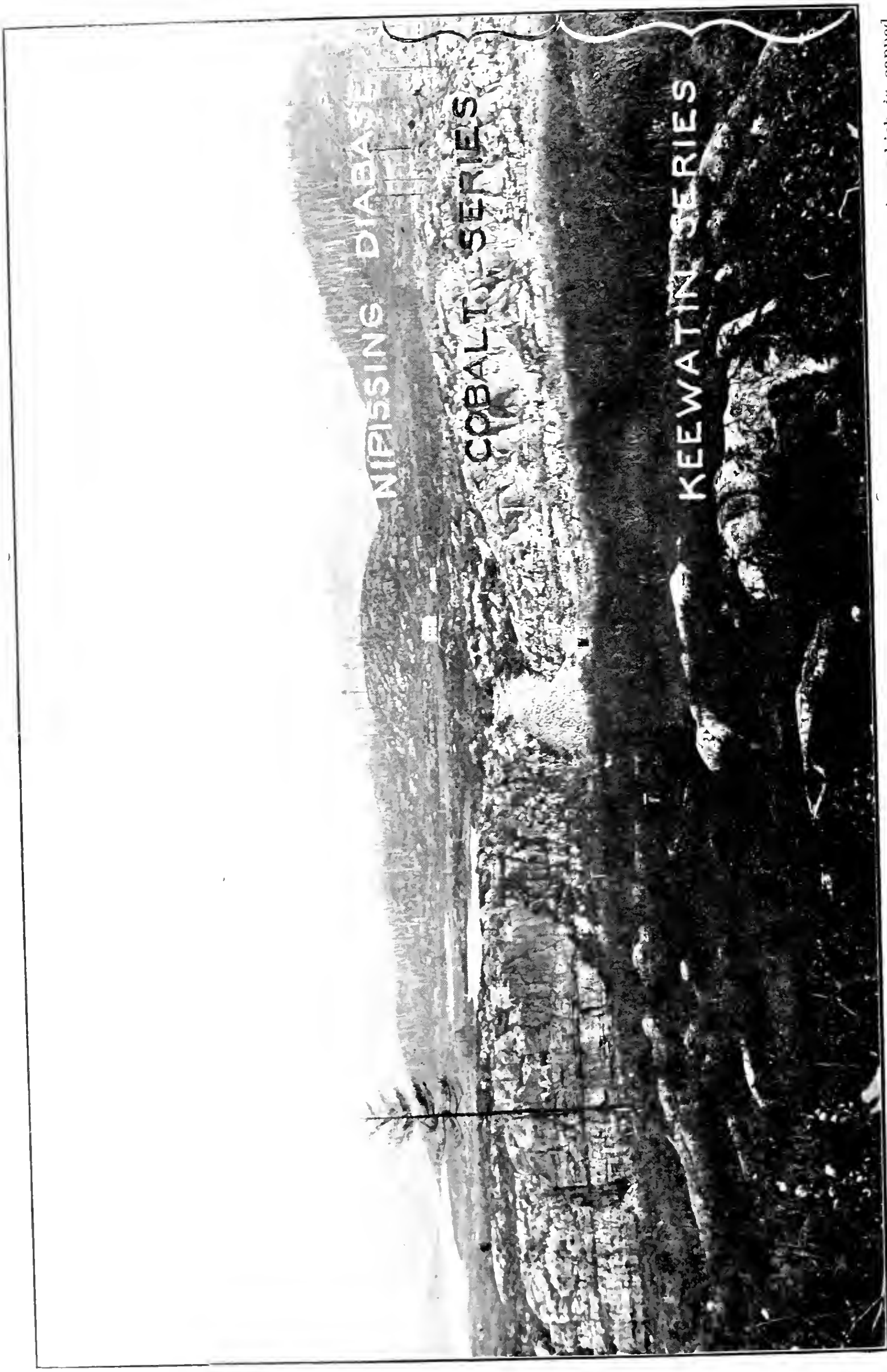


Fig. 20. Keewatin greenstones in the foreground, covered by conglomerate and slate-like greywacké of the Cobalt series, which is capped by the Nipissing diabase sill. The photograph was taken from the hill at the McKinley-Darragh mine, the camera pointing easterly.

THE ROCKS AND THEIR RELATIONSHIPS

At first, owing to the surface being covered with green timber and to the presence of much drift material, contacts and good exposures were difficult to find. Facilities for mapping have been much better during late years, as mining has progressed and the timber has been removed.

From the maps which accompany this Report it will be seen that there is considerable variety in the pre-Cambrian series. The Niagara of the Silurian system also shows prominent outcrops. Between the Niagara and the Pleistocene or Glacial there are no formations represented in the district.* The author is indebted to Mr. Cyril W. Knight for many of the descriptions of rocks on following pages.

The following table shows the subdivisions, based on age relations, that have been made among the rocks of the Cobalt area proper. Representatives of most of these subdivisions of the pre-Cambrian are found in other areas that have been carefully mapped in the surrounding region.

In the Porcupine gold area, one hundred miles to the northwest of Cobalt, the Keewatin and Temiskaming series are prominent. The Cobalt series is also present in this area, and certain dikes are believed to represent the Nipissing diabase of Cobalt.

In the Gowganda area, which lies fifty miles to the west of Cobalt, the Nipissing diabase and Cobalt series occupy much of the surface. The Temiskaming series is found in good exposures in part of the area. The latter series has also been found at Swastika and Larder Lake, at Abitibi Lake, 75 miles north of Cobalt, and eastward across the boundary in Quebec. It is thus known to occur at various points over a large region. (Fig. 21, map.)

It is possible that unconformities that have not been discovered exist in the pre-Cambrian of the Cobalt and adjacent areas. Moreover, the relationship which the

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*Sir William Logan (then Mr. Logan) explored Lake Temiskaming in 1845-6. The account of his trip, published in the report of the Geological Survey for those years, pages 60-70, is of interest.

"Ascending Lake Temiscamang, the slates come in upon the gneiss about three miles below the mouths of the Montreal and Metabecchuan Rivers, on the west bank, and about three miles above them on the east; and they occupy both sides to within two and a half miles of the Hudson Bay Company's Post. In this distance they may have a direct breadth of about seven miles in which they are effected by at least one undulation, and probably more, and constitute hills of 300 to 400 ft. As gathered from the map of Mr. D. Taylor's exploratory journey from Lake Huron to the Ottawa by Lakes Nipissing, Temagamang and Temiscamang, the slates in a westerly direction run forty miles in a line about S. 40° W., from the latter Lake to Bass Lake, on the Sturgeon River, which discharges into Lake Nipissing on the north side, and it appears probable they will come upon some part of the north shore of Lake Huron. On Lake Temiscamang they are followed by the sandstones, which cross the lake with a strike of N. 60° E., and dipping northward at a very small angle, after having been piled up into a range of about the same elevation as the slate hills, they reach the Company's Post, where, nearly flat, they run under a narrow gravel hill, 130 feet in height; emerging beyond, they continue to a distance of about half a mile above the Post, and there become interrupted on both sides of the lake by a mass of syenite. This syenite does not possess the gneissoid arrangement of the rock lower down the river, but it appears to be nearly similar in other respects, being composed of reddish feldspar, white or colorless quartz and a sparing quantity of green hornblende. The breadth of this syenitic band is pretty nearly three miles on both sides of the lake. On the west it is succeeded by the sandstones, which run along the coast for a distance of four miles, nearly in the strike of the measures, dipping towards the water at a small angle, and are followed by the slates, which come from behind them, and continue in a straight line for nine miles to the western bay at the head of the Lake, forming high, perpendicular cliffs for part of the way, and rounded hills for the remainder. On the east side, the syenite gives place to the slates, which there present the porphyritic appearance already mentioned. The sandstones come upon them on the south side of the southern large island, and the mainland near, dipping a little to the west of north at an angle of three degrees; and both they and the slates, with their associated conglomerates, make their appearance at occasional points along the coast, wherever denuded of the overlaying limestones the basset edge of which thinly covers them, to the island at the entrance of the eastern or Moose River Bay. Beyond this the sandstones, gently dipping south, are seen in a projecting point to the east of the island. The slates are met with at the mouth, and at the first, second and third portages of the Riviere des Quinze, or Moose River, and their associatiated conglomerates in the bay to the west of the Blanche.

"The limestones constitute the two large islands north of the Company's Post, the two smaller ones between them, the island already mentioned planted at the entrance of the eastern bay, and a very small one on the west coast, as well as the promontory which separates the east bay from the west. The strata lie in the form of a shallow trough, based sometimes on the sandstones and sometimes on the slates, occupying the breadth of the lake,—from five to six miles—and extending from the south side of the southern great island to some unknown distance northward, being probably either a projecting point or an outlier of some more extended calcareous area nearer Hudson's Bay."

Cobalt and Temiskaming series have to the fragmental rocks of the classic Huronian area of the north shore of Lake Huron is not known. Hence, in the following table the name Huronian is not employed, although elsewhere in the report the name is applied in a general way to the Cobalt series. If the Huronian is considered to include all the post-Laurentian and pre-Keweenawan fragmental rocks of the region, then both the Cobalt and Temiskaming series come under this heading.

As shown by the accompanying foot-note, Sir William Logan visited Lake Temiskaming in 1845. Among the rocks he described on the shores are what are now known as the Cobalt and the Temiskaming series, both of which outcrop at the water's edge, on the west side of the lake. In the report for 1848, the same author described the fragmental rocks on the north shore of Lake Huron, extending from the vicinity of Sault Ste. Marie to Killarney. In the report for 1863, the rocks of Lake Temiskaming, those of the north shore of Lake Huron and those at the mouth of the Doré River on Lake Superior and in other localities are classed as the Huronian series. While emphasis was laid on the fact that the members of this series all contain fragments of granite and gneiss, thus showing them to be younger than the series to which the name Laurentian was applied, it was also recognized that at certain localities there is granite and gneiss younger than the Huronian, as the following quotations from the report of 1863 show: "On the coast line between the Mississagui and Thessalon Rivers, a distance of about twenty-five miles, the gneiss extends from within about four miles of the former to within about the same distance of the latter; but it is very much disturbed by intrusive granite and greenstone, and, although there are great exposures of rock, it is very difficult to make out how the stratified portions are related to one another. The gneiss extends to the vicinity of a small stream about a mile and a half above Les Grandes Sables, and what is supposed to be the lowest Huronian mass of that part occurs about half a mile above the stream. It consists of a grey quartzite which abuts against one mass of gneiss and runs under another, and appears to be much broken by and entangled among the intrusive rock; but judging from a transverse measured in one part, its thickness would not be far from 500 feet. . . . .

" . . . The intrusive granite occupies a considerable area on the coast of Lake Huron, south of Lake Pakowagaming. It there breaks through and disturbs the gneiss of the Laurentian series, and forms a nucleus from which emanates a complexity of dykes, proceeding to considerable distances. As dykes of a similar character are met with intersecting the rocks of the Huronian series, the nucleus in question is supposed to be of Huronian age, as well as the greenstone dykes which are intersected by it."

From these quotations it would appear that there may be two series of fragmental rocks in Logan's Huronian group on Lake Huron, one intruded by what he calls Huronian granite and another not so intruded. These groups probably correspond to the younger Cobalt and the older Temiskaming series which are found at various points in the region to the northeast. In the younger series of Lake Huron there may also be an unconformity of lesser importance, comparable to that between the lower greywacké of the Cobalt series and the upper or Lorrain arkose. Fine-grained fragmental rocks, comparable in age to the Grenville series of southeastern Ontario, are known to occur at various points in the Cobalt-Lake Huron region. Unless great care is taken, these rocks, which are pre-Laurentian in age, are apt to be mistaken for the Huronian.

Descriptions of other authors tend to confirm the opinion that there are at least two groups of sediments on the shores of Lake Huron with a great unconformity between them. For instance, Alexander Winchell, from observations made in 1890 and 1891, concluded, from difference in metamorphism and great discordance in dip, that there are two series in the lake Huron area: "It is concluded that the name Huronian must be restricted to the upper or lower system; and if restricted to the upper system it remains attached to the best known and most characteristic portion of the old complex Huronian."*

* Quotation taken from Bull. 360, U.S.G.S., p. 412.

The quotations in preceding paragraphs show that Logan recognized granites and granite-gneisses of at least two ages in association with the rocks named by him Huronian. To the granites and gneisses older than the Huronian he gave the name Laurentian. Since Logan's time many outcrops of granite and gneiss, owing to the difficulty or impossibility of determining their ages, have been classed as Laurentian. Gradually, however, areas of granite, some of which are of large size, are being found to be intrusive into part of the fragmental rocks, named Huronian by Logan, and are being given distinctive names. Thus, in the vicinity of Lake Temiskaming, an area

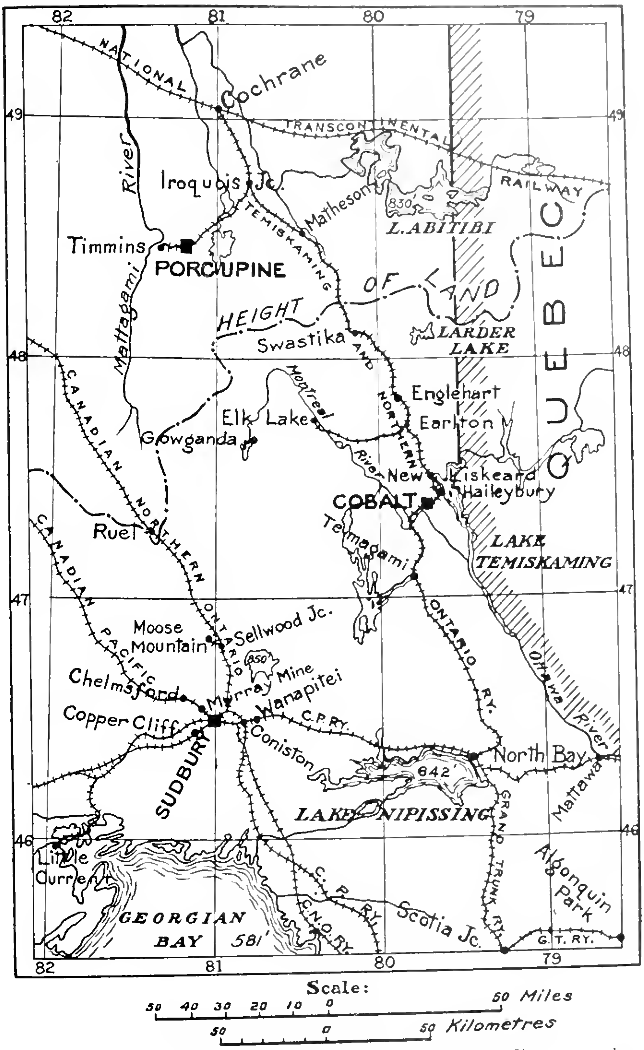

Fig. 21. Index map of the Cobalt-Porcupine-Sudbury region.

of granite 40 or 50 square miles or more in extent, formerly called Laurentian, has been found to intrude the Temiskaming fragmental series but not the Cobalt series. The granite has been given the name Lorrain, as shown in the following table. Areas of granite with the same relations to the Temiskaming and the Cobalt series have been described at Swastika, Porcupine and elsewhere. The Laurentian is thus being gradually reduced in volume, but the name is retained for those granites and gneisses that are older than the Temiskaming series, which frequently contains pebbles and boulders of these rocks.

The dual subdivision of the pre-Cambrian into Algonkian and Archean, or Proterozoic and Archeozoic, employed by many authors, is not adopted by the writer, since he believes that the Grenville series, which includes limestones and other sediments of great thickness, is of pre-Laurentian age. The thickness of the sediments in the Grenville and the character of the deposits make it inadvisable to attempt to subdivide the pre-Cambrian into an upper characteristically sedimentary group, above the Grenville, and a lower igneous complex including the Grenville sediments. The subdivision into Proterozoic and Archeozoic groups, the latter including the Grenville, is purely arbitrary. Thus a dual subdivision of pre-Cambrian rocks, based on arguments that have been employed in its behalf, fails. If a name is desired for the pre-Cambrian rocks, to correspond with Paleozoic and Mesozoic, the well-known name Eozoic may be used.

Age Relations of Rocks of Cobalt and Adjacent Areas

PALEOZOIC	
SILURIAN Niagara	Prominent outcrops of Niagara limestone, with basal conglomerate and sandstone, occur on some of the islands and the shores of the north end of lake Temiskaming.
(Great unconformity)	
EOZOIC OR PRE-CAMBRIAN	
LATER DIKES	Aplite, diabase, basalt.
NIPISSING DIABASE *(Intrusive contact)*	This diabase, which is of such great interest in connection with the cobalt-silver veins, is believed to be of Keweenawan age. Certain aplite dikes are genetically connected with the diabase.
COBALT SERIES *(Unconformity)*	The Cobalt series includes conglomerate, greywacké and other fragmental rocks.
LORRAIN GRANITE *(Intrusive contact)*	This granite occupies a considerable part of the township of Lorrain and has large exposures elsewhere in the vicinity of lake Temiskaming.
LAMPROPHYRE DIKES *(Intrusive contact)*	Lamprophyre dikes are to be seen near some of the mines at Cobalt.
TEMISKAMING SERIES *(Unconformity)*	Like the Cobalt series, the Temiskaming consists of conglomerate and other fragmental rocks.
KEEWATIN COMPLEX	The Laurentian, gneiss and granite, which in age lies between the Keewatin and Temiskaming, is absent in the Cobalt area proper, but is found in the surrounding region. Under the heading Keewatin are grouped the most ancient rocks of the region. They consist essentially of basic volcanic types, now represented by schists and greenstones, together with more acidic types, such as quartz-porphyry. With the Keewatin are included certain sediments, such as iron formation or jaspilyte, dark slates and greywackés, which probably represent the Grenville series of southeastern Ontario. Certain dike rocks that are grouped with the Keewatin may be of post-Temiskaming age, but since they have not been found in contact with the Temiskaming their age relationships are unknown.

Maps and Sections

The distribution of the rocks in the area immediately surrounding Cobalt, and in Gowganda and Elk Lake, is shown on the maps to which reference is made in the following paragraphs.

In preparing the original geological map of the Cobalt area on a scale of one mile to the inch, in 1904, I had the valuable assistance of Messrs. Cyril W. Knight and R. Anson-Cartwright. This map has gone through four editions. The last edition was partly revised by Mr. James Bartlett, a former member of the staff, and was enlarged so as to include the Gillies' timber limit, the South Lorrain area and the township of Casey, which lies to the north of the head of lake Temiskaming.

In 1906 Mr. Knight took charge of the work of preparing a detailed map of the more productive part of the area. This map is on a scale of 400 feet to the inch, with contour intervals of 10 feet over the more important part of the area. It was published at the end of 1907 and accompanies the third edition of the report.

The uncolored map of a part of the Cobalt area, scale 800 feet to 1 inch, has been revised and accompanies this report. It shows the distribution of the rocks, the position of the veins, and the location of the geological sections that are published with this edition of the report.

A colored geological map of the Gowganda area, scale 1 mile to 1 inch, prepared by Mr. A. G. Burrows, has been published since the third edition of the report was issued.

A geological map, scale 1 mile to 1 inch, of the Montreal river and Elk lake area, was distributed with the third edition of the report.

The colored cross sections that accompany this report went to press in Dec., 1911. Second editions of some of these sections have recently been prepared and are to be found on following pages. They are uncolored, and contain further information than was obtainable at the time the first editions were published. The plates illustrating the cross-sections are numbered I.-VI..

Fig. 22. Lang street, Cobalt, September, 1911.

THE KEEWATIN COMPLEX

The Keewatin rocks, of the Cobalt area proper, may be described under four groups: (1) Basalts, (2) Diabases and other basic rocks, (3) Acid intrusives, (4) Sediments.

The following descriptions of types of Keewatin rocks are by Mr. Cyril W. Knight.

(1) BASALTS

The basalts are the most common rocks found in the Keewatin complex. Typical outcrops occur at many points, a few of which may be mentioned.

Northwest of Contact bay, in Giroux lake, near the branch of the Temiskaming and Northern Ontario Railway, there is a fine outcrop. Fig. 23 gives a good idea of the ellipsoidal structure commonly found in these rocks. Similar rocks occur at the Shamrock, Temiskaming, Columbus and other mines. On the southern outskirts of the town of Haileybury, along the shores of lake Temiskaming, the steep banks have typical outcrops of the basalts, showing in certain areas ellipsoidal structures.

Although the basalts have been much decomposed and have been subjected to metamorphic agencies, they are, on the whole, massive rather than schistose. An amygdaloidal variety occurs at the head of Sasaginaga creek.

The rocks are fine in grain and have a prevailing green color, due chiefly to chlorite and other secondary minerals, such as serpentine and epidote. The groundmass commonly consists of plagioclase feldspar in lath-shaped crystals presenting the pilotaxitic texture, and showing more or less of flow structures. The original ferro-magnesian minerals in the groundmass appear to have been altered to secondary minerals, such as chlorite, and calcite. Glass has not been found in any of the thin sections examined. The original ferro-magnesian phenocrysts also seem to have been decomposed, but plagioclase phenocrysts occur, showing albite twinning lamellae. Porphyritic varieties may be seen on the O'Brien and Ferland-Chambers properties. Many thin sections have been examined of these basalts from surface outcrops and from underground workings. A description of some of these is given in the following paragraphs.

The greenstone immediately west of the Coniagas is typical of much of the Keewatin at Cobalt. It is a light greenish-colored rock, having tiny veinlets of chlorite, epidote, hornblende, calcite and iron sulphides ramifying through it. Under the microscope the rock is seen to be a decomposed basalt, consisting of a groundmass of plagioclase rods, in which are set phenocrysts of plagioclase and a colored constituent which is altered to chlorite. The groundmass contains, in addition to the feldspar rods, much secondary material, consisting of chlorite, epidote and hornblende.

A thin section from the Nipissing, between vein 49 and Cobalt lake, shows numerous plagioclase rods, together with chlorite, titanite, magnetite and much iron pyrites. The basalt in this area is stained with limonite, due to the decomposition of the sulphide.

Nine hundred feet east of the north end of Cobalt lake, at the main road, on the Ferland-Chambers, two veins are shown on the Cobalt map, scale 400 feet to an inch. An open cut affords good samples of the Keewatin here. The rock is porphyritic, the phenocrysts consisting of greyish green rods one-quarter inch long. Under the microscope these phenocrysts are seen to have been entirely decomposed and to consist now almost wholly of chlorite, together with smaller quantities of titanite, calcite and feldspar (sometimes twinned). The chlorite is the variety penninite, giving the deep indigo blue interference colors with crossed nicols. The phenocrysts are set in a groundmass which is made up dominantly of irregular plagioclase laths showing albite twinning lamellae, giving a maximum extinction angle of 20 degrees in the zone normal to the twinning plane. Subordinate quantities of calcite and titanite also occur in the groundmass.

The rock fifty feet south of the large bunkhouse on the O'Brien mine is somewhat similar to that just described. The thin section, however, shows that it is more decomposed, and consists of a fine-grained groundmass of chlorite (variety penninite), biotite, titanite, quartz and magnetite. In the fresher parts of the matrix, rods of plagioclase may be distinguished. Phenocrysts similar to those described in the preceding paragraph are set in the matrix.

A silica determination from the rocks described in the last two paragraphs gave 51.04 and 53.8 per cent. respectively. This silica content corresponds with that in the more acid basalts.

Fig. 23. Ellipsoidal basalt, north of Contact Bay, Giroux Lake, Cobalt.

A thin section from the Keewatin on the Watts (King Edward) shows it to be made up essentially of a network of feldspar rods, green allotriomorphic hornblende grains, and chlorite. Calcite, quartz, pyrite and titanite are present in smaller amount. In parts of the section plagioclase phenocrysts occur in the groundmass. Cutting across the slide there are microscopic veinlets containing hornblende.

The Keewatin on the west part of the Silver Bar property is fine-grained and in places schistose. Under the microscope it is seen to consist largely of rods of plagioclase, usually twinned once and much altered. In the more decomposed areas chlorite, hornblende, biotite, magnetite and other secondary minerals replace the feldspar rods. The section is ramified by tiny veinlets containing chlorite, quartz, hornblende, etc. The rock was found by analysis to contain 53.24 per cent. of silica, which is about the silica content of the more acid basalts or basic andesites.

West of Contact bay, Giroux lake, a thin section of the basalt consists of chlorite and laths of plagioclase feldspar. Epidote and zoisite occur, partly scattered through the groundmass and partly in tiny veinlets.

Basalts similar to those on the surface have also been found in the underground workings of many of the mines. On the 150-foot level of the McKinley-Darragh, 15 feet southeast of the great fault plane, the rock is a very fine-grained greenstone, consisting of plagioclase rods, hornblende, chlorite, and other minerals. On account of its proximity to the fault it has been crushed into fragments. In another part of the same level a thin section of the Keewatin shows a fine network of plagioclase laths, in the interstices of which are secondary minerals, such as chlorite and mica. Again on the third level the basalt is distinctly porphyritic, showing relatively large phenocrysts of plagioclase.

At La Rose mine, main shaft, on the second level, a specimen two feet north of the shaft shows one of the least altered basalts met with. It consists of the usual feltwork of plagioclase rods lying in saussurite, etc. Although the ferro-magnesian minerals appear to be altered to secondary material, the plagioclase laths are comparatively unaltered. Three thin sections were examined from the rock between the second and third levels and were found to be basalts or andesites, consisting of a fine-grained matrix of feldspar laths and secondary ferro-magnesian minerals. Occasional phenocrysts of plagioclase occur in this matrix. One of the specimens is much brecciated, probably owing to its proximity to the great fault. (See plate V.)

Basalt, felsite and chert occur on the 188-foot level, shaft No. 8, of the Lawson. The basalt is much decomposed, but a feltwork of fine plagioclase rods can still be seen in parts of the thin section. Much of the slide is made up of chlorite, calcite and saussurite.

A specimen from the Foster, at the 50-foot level of what in 1906 was known as the air-shaft, consists of chlorite, biotite, feldspar and magnetite, the feldspar occurring in rods.

Thin sections from the first and second levels of the Temiskaming mine show the rock to be made up of a feltwork of plagioclase rods which are set in a groundmass of epidote and other secondary material. A specimen from the winze on the fifth level, 540 feet below the surface, is found to be a fine-grained greenstone, apparently completely altered to secondary minerals—hornblende, saussurite, quartz, etc.

Diamond drill holes have been put down in the Keewatin at some of the properties. A thin section from a core on the Trethewey at a depth of 661 feet consists largely of secondary minerals of which calcite predominates. Epidote and sericite also occur. A few plagioclase rods may be recognized in this groundmass, disclosing its igneous origin. Another section from this core at a depth of 765 feet is similar to that at 661 feet. The hole was drilled at an angle of 62 degrees.

A drill hole was also put down on Dynamite island, Giroux lake. After passing through the Nipissing diabase the Keewatin greenstone was encountered; thin sections were examined from 375, 378 and 511 feet below the surface. These sections are made up of plagioclase rods, together with epidote, chlorite, etc., the last two mentioned minerals sometimes predominating.

Fig. 24. Characteristic weathered surface of fine-grained Keewatin greenstone, McKinley-Darragh, Cobalt

(2) DIABASES AND OTHER BASIC ROCKS

The diabases are of common occurrence in the Keewatin complex, although they are not as widely distributed as the basalts. They are fine to coarse grained, massive rocks, often showing a distinct ophitic texture in hand specimens. Ordinarily it is not difficult to distinguish this group from the Nipissing diabase, because the former has a characteristic "old" appearance which is soon recognized during work in the field. This "old" appearance is simply due to the decomposed state of the ferro-magnesian minerals and the plagioclase. As compared with the basalts, the Keewatin diabases are generally coarser in grain and fresher. A prominent intrusion occurs west of the Trethewey, Coniagas and Buffalo properties, while at the Temiskaming a well-defined dike is found a few hundred feet west of the shaft running in a northerly direction through the property. Other occurrences are mentioned below in connection with the microscopic descriptions.

Two thin sections were examined from the diabase immediately west of the Trethewey. They consist of plagioclase, hornblende, chlorite, epidote, zoisite, serpentine and leucoxene. The plagioclase occurs in rods and in many cases is altered to saussurite, but frequently albite twinning lamellae may be recognized, giving maximum extinction angles in sections normal to the lamellae of 20 degrees. The hornblende, which sometimes is in grains a quarter of an inch long, is the common green variety, occurring partly in more or less regular grains and partly in confused fibrous areas associated with chlorite and epidote. Parts of the sections show plagioclase rods embedded in the hornblende, giving a distinct ophitic texture to the rock. A section from the southwest corner of the Buffalo is also seen to be a much altered diabase. The freshest material present is hornblende, although much of this mineral is altered to chlorite. The feldspar is generally completely gone to secondary products, but some is fresh enough to show albite twinning lamellae. Distinct traces of an ophitic texture occur, showing rods of plagioclase largely altered to saussurite embedded in hornblende; the latter may have resulted from the alteration of pyroxene. A thin section from this diabase intrusion on the western edge of the Trethewey mine did not disclose an ophitic texture, and this part of the mass might be classed with the diorites, or gabbros.

A fine-grained diabase occurs on the 125-foot level of the No. 1 shaft of the Hargrave. On account of the proximity of the Nipissing diabase, a microscopic examination may not be definitely relied upon to correlate this rock with the older diabase; but if the fine-grained texture and decomposed condition be taken into consideration, it may tentatively be grouped with the older rocks.

On the third level of the Crown Reserve fine-grained diabase and other rocks occur. The diabase consists essentially of plagioclase feldspar and hornblende showing ophitic texture; both minerals are partly decomposed to the usual secondary products.

A section was examined from the 88-foot level of a shaft which was originally believed to be on the Silver Leaf, but which recent surveys have proved to be on the Lawson. The rock is a fine-grained diabase made up of plagioclase, hornblende, quartz, chlorite and saussurite. A poorly defined ophitic texture occurs.

On the 300-foot level of the Lumsden, 145 feet south of the shaft, the rock is a fine-grained, altered diabase, showing traces of an ophitic texture. It consists essentially of plagioclase and hornblende, together with the usual decomposition products. A specimen from another part of the same level is a very fine-grained greenstone, much decomposed, and consisting of plagioclase, hornblende, biotite and other minerals.

The basic dike previously mentioned as occurring on the Temiskaming a few hundred feet west of the main shaft shows in parts of its mass distinct ophitic texture, while in other parts it lacks this texture. For descriptive purposes, however, it is grouped with the diabases. The rock is well exposed on the surface, and has also been met with on a west drift from the second level. It varies in grain from fine to medium. Ten thin sections were examined, in six of which distinct ophitic textures were found. The dike consists now essentially of two minerals, hornblende and plagio-

clase, while quartz, leucoxene, chlorite, pyroxene, saussurite and other minerals are subordinate in amount. In a few cases it can be clearly seen that the hornblende is secondary after pyroxene. Quartz occurs sometimes in beautiful micrographic intergrowths with feldspar.

Thin sections from the Argentite (the southeast corner of the northeast quarter of the south half, lot eight, in the fifth concession of Coleman township), were examined by M. B. Baker in the laboratory of Prof. Rosenbusch, Heidelberg, Germany. Mr. Baker found the rock to consist of a fibrous, felt-like groundmass of talc, muscovite, saussurite and plagioclase. Scattered through this matrix are hypidiomorphic to idiomorphic crystals of diallage. Mr. Baker considered the rock to be a dolerite or diabase. A chemical analysis was made of the diallage by Mr. N. L. Turner, and it was found to have the following composition:

Fig. 25. Torsion cracks in Keewatin greenstone, lot 15 in the second concession of Bucke.

SiO_2	48.92
Al_2O_3 / Fe_2O_3	18.88
CaO	12.16
MgO	18.00
Combined water	2.56

(3) ACID INTRUSIVES

The acid igneous rocks of the Keewatin, which are not widely distributed in the Cobalt area, include felsite, feldspar-porphyry and quartz-porphyry.

At the north end of Sasaginaga lake an occurrence of a white to light grey felsite presents a striking appearance on account of its light color. It is fine in grain and comparatively fresh, and consists of feldspar and quartz, the feldspar predominating. The rock has a micro-porphyritic texture, due to the presence of phenocrysts of feldspar and quartz. Often the feldspar rods in the matrix are arranged in parallel lines, which curve around the phenocrysts, producing what is known as a

flowage texture. Colored constituents appear to be absent. Some secondary calcite is present, with which also occurs some secondary quartz. Most of the feldspar shows albite twinning lamellae. One of the thin sections examined has a fragmental appearance, and there is developed in and around the feldspar grains sericitic material.

Felsites are also known in the underground workings of the Lawson and Crown Reserve. On the 188-foot level of the former the felsite consists of plagioclase and quartz, together with calcite, chlorite and other secondary material. On the 88-foot level of this mine similar rocks have also been met with. These felsites are probably of intermediate composition, judging from the presence of plagioclase and the subordinate part played by quartz.

On the third level of the Crown Reserve thin sections of part of the rock showed it to be a felsite, and to consist of short plagioclase rods, together with chlorite, biotite and quartz.

In the No. 5 shaft at the 130-foot level of the Drummond mine there occurs a fine-grained, fresh feldspar-porphyry. It is made up of phenocrysts of an acid plagio-

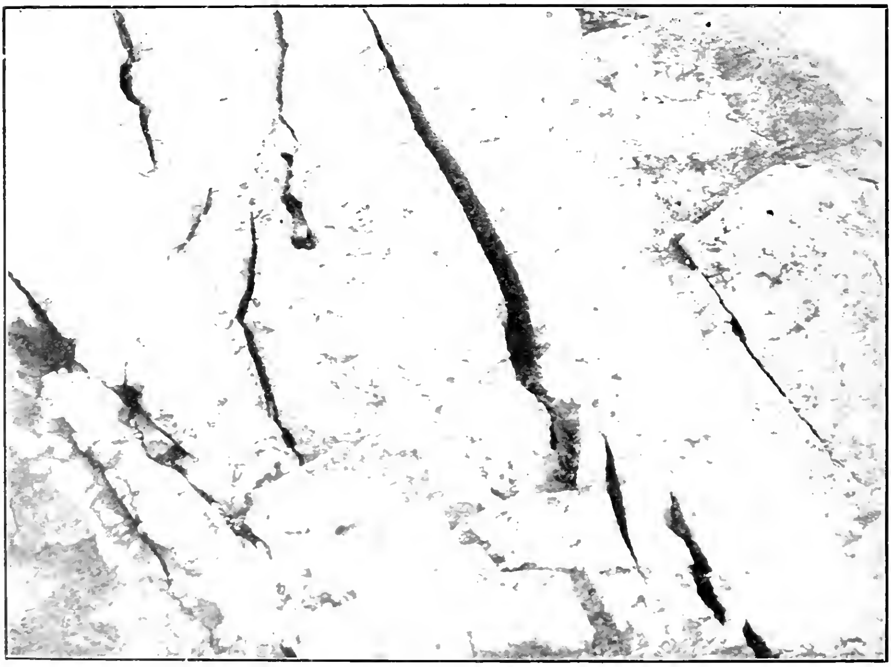

Fig. 26. Part of rock surface in Fig. 25 enlarged.

clase feldspar, set in a fine-grained matrix of feldspar, biotite and probably some quartz. At the 125 and 75-foot levels of the No. 1 shaft and on the third level of No. 3 shaft of the Hargrave similar feldspar-porphyries occur.

South of Haileybury, on lot 15, in the second concession of Bucke, there is exposed on the shore of lake Temiskaming a dike of quartz-porphyry which cuts the fine-grained greenstones. The dike is medium in grain and grey in color. The groundmass consists of tiny feldspar rods and quartz, together with chlorite, which, however, is subordinate. The phenocrysts consist of "eyes" of quartz and plagioclase feldspar, the latter showing crystal outlines. Apparently phenocrysts of a ferro-magnesian mineral were also once present, but they have been altered to chlorite.

The acid types occur in greater volume on the Quebec side of Lake Temiskaming, and are shown in the geological map prepared by Mr. Morley E. Wilson.*

*Map No. 1067, Geological Survey of Canada, Ottawa, 1907.

The igneous, Keewatin rocks, both basic and acid, frequently contain torsion cracks of striking appearance (Figs. 25, 26). These cracks, filled with white calcite or dolomite, serve to distinguish the Keewatin rocks from certain of those of the Cobalt series which overlie them. Otherwise, the Cobalt rocks that have been derived directly from the Keewatin, are indistinguishable from the latter except in thin sections under the microscope.

(4) SEDIMENTS

The sediments grouped with the Keewatin include iron formation (jaspilyte, chert and greywacké), graphite schists and slates.

The iron formation is exposed in several places between Kerr lake and the south end of Cross lake. Of this formation the red jaspilyte facies is of very subordinate distribution, but a few contorted bands several inches wide are exposed. In so far as our studies have gone, it would appear that the three members of the iron formation mentioned (jaspilyte, chert and greywacké) belong together in a conformable sequence. Under the microscope the cherts are seen to consist of quartz and feldspar grains, the former largely predominating. Chloritic and sericitic minerals also occur together with iron oxides. Microscopic veins of chlorite and quartz ramify through the rock. These dense, fine-grained, chert-like rocks pass into typical greywackés, composed of angular fragments of quartz and feldspar set in a matrix of chloritic and sericitic minerals. In one case there were, in addition to the minerals, fragments of felsites and basalts.

Graphite schists occur sparingly north of Clear lake and in the underground workings of La Rose and Columbus mines. A quantitative analysis of the schist from the Columbus showed 7.07 per cent. graphitic carbon and an absence of manganese. A thin section from the schist at the third level of La Rose, east of the great fault, shows the rock to be a greywacké, consisting essentially of angular fragments of quartz and feldspar. The graphite not only forms a matrix for these fragments but it also occupies the central part of many of the feldspar grains, in some cases, indeed, almost completely filling the interior, so that the feldspar itself forms merely an outer shell. The outline of several of the feldspar grains is interesting. While most of them are angular and irregular in shape, a few, however, have a short, stubby cylinder or cigar-like contour with pointed ends; others consist only of the pointed end of one of the cylinders. These peculiar grains also hold graphite under conditions similar to those found in the other fragments just described. It may be added that an organic origin of the pointed, cylindrical grains might be suspected by a casual examination.

At the head of Sasaginaga creek on the north side, near the old dam, a grey slate occurs, resting in a vertical position. Whether this belongs structurally with the Keewatin iron formation, or whether it is part of the Temiskaming series is not yet definitely known. In close association with it are found amygdaloidal lava and chert. The slate was found to have the following composition:

SiO	60.29
Fe_2O_3	1.64
FeO	5.77
Al_2O_3	21.10
CaO	.35
MgO	1.62
Na_2O	2.60
K_2O	3.19
H_2O	3.84
MnO	....
	100.40

Relationships

The various basalts, diabases, acid intrusives and sediments described above have not been seen directly in contact with the Temiskaming series or Laurentian granites proper, but for reasons given in another part of this Report they are classed with the Keewatin. The sediments, however, probably here represent the Grenville series of southeastern Ontario, which is to be described more fully in a forthcoming report by Mr. Cyril W. Knight and the present writer.* Regarding the relationships of the rocks to one another, it is known that some of the diabases are intrusive into the basalts and iron formation; the diabase dike at the Temiskaming, for instance, invades the fine-grained greenstones there, and the diabase intrusion west of the Trethewey invades an iron formation (chert). Regarding the fine-grained diabases at the Crown Reserve, Lawson and Lumsden, it may be that they are merely facies of the basalts. The quartz-porphyry dike, south of Haileybury (lot 15, in the second concession of Bucke) intrudes the fine-grained greenstones. The relationships of the intrusive diabases and acid rocks to each other are not known, since they have not been found in contact. The felsite on the north part of Sasaginaga lake is cut by a lamprophyre dike, while at Kirk lake these lamprophyres are cut by the Lorrain granite.

The Keewatin of the Gowganda and Elk Lake silver-cobalt areas is described on following pages. It is much like that of Cobalt, as is also that of the Porcupine gold area.

Ores of the Keewatin

Associated with the greenstones or schists of the much disturbed Keewatin are characteristic ores, in addition to those of cobalt and silver described on other pages.

These rocks are found in numerous localities in northern Ontario, between the western boundary of Quebec and the eastern boundary of Manitoba. In many places they are iron-bearing, the typical iron formation or jaspilyte being composed of interbanded magnetite or hematite with jasper or some other closely related silicious material.

These outcrops of the iron formation, or iron ranges as they are called, have attracted the attention of many writers. Some of the most important of them in northern Ontario are the following: those of lake Temagami; that in the township of Hutton; the Michipicoten iron range; and farther west the Mattawin and the Atikokan. In fact, all of the iron ranges of the northern part of the Province, with the exception of those in the Animikie or Upper Huronian series in the vicinity of Port Arthur and the titaniferous iron ores which are found in a number of places, belong to the Keewatin. There are two or three interesting occurrences in the area under review which show that this Keewatin iron formation has at one time been well developed here. Immediately south of Sharp Landing, near the shore of Temiskaming, there is an outcrop of the interbanded material, which is only about 25 feet in length. No other rocks of the Keewatin are here exposed, the Temiskaming series being distributed over the rest of the surface in the locality. The rocks of the latter series consist of conglomerate and greywacké. The pebbles in these show numerous representatives of the iron formation. Smaller outcrops of the iron formation are found near Cobalt.

A Buried Iron Range

It is thus seen that at Sharp Landing we have a portion of a buried iron range. The strike of the interbanded material in the exposure is somewhat north of west. In the outcrops of conglomerate, which are shown on the map, in the township of Hudson are found large blocks of this iron formation in the direction from the outcrop at Sharp Landing represented by the strike of the interbanded material at the Landing. We have thus good evidence that the iron range or formation lies at no great distance from the surface in this part of Hudson. Between these outcrops of conglomerate and Sharp Landing the range is cut through by diabase and it is over-

*22nd Report, Ontario Bureau of Mines, Part II.

lain by Niagara limestone and recent clay deposits, in addition to the Temiskaming and Cobalt series. This iron range no doubt extends farther west than Hudson. It has been covered up since Temiskaming times, as shown by the fact that it is overlain by rocks of this series, and has therefore not been subjected to glaciation, which is supposed to have produced injurious effects on the iron deposits of Ontario, it having been held by some writers, for instance, that the soft ores in these deposits have been gouged out and carried to the southward. Near the southeast corner of Cross lake in the township of Coleman there is a small exposure on the shore which also carries large angular blocks of the iron formation. We have found the iron formation in place, in the area which we have mapped as Keewatin, a short distance northeast of the Drummond mine. Much of the conglomerate in various parts of the area contains jasper pebbles and other material derived from the iron formation.

In addition to the iron ranges mentioned, there are outcrops of similar material in the township of Boston to the northward. Certain beds or series of beds in the Temiskaming series resemble the iron formation of the Keewatin.

Iron Pyrites

The iron pyrites deposits of this part of Ontario also belong to the Keewatin. One of these is shown on the map near the Montreal river, south of the township of Coleman. Others have been worked still farther to the southward between this point and lake Temagami.

Copper pyrites in the Keewatin has attracted attention at numerous places. Deposits of the mineral in the township of Lebel, along the upper parts of the Blanche river and in the vicinity of Temagami, have been worked.

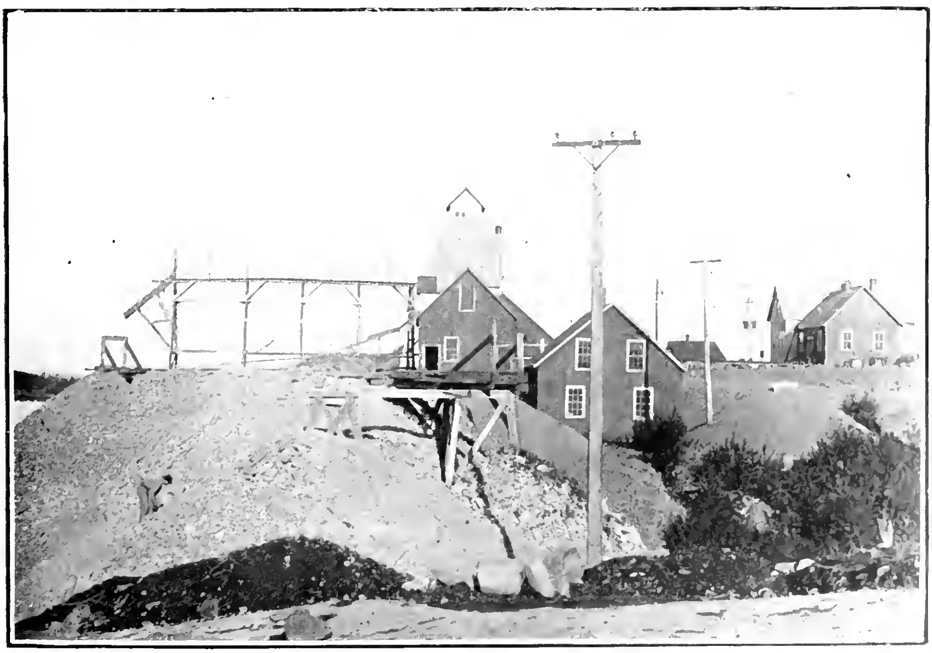

Fig. 26a. Kerr Lake mine, Cobalt.

THE KEEWATIN-LAURENTIAN COMPLEX

No granite, or granite-gneiss, older than the Lorrain granite, occurs in the immediate vicinity of Cobalt, nor has such a granite or gneiss been described in the vicinity of Gowganda, Elk Lake or other outlying silver areas of the Temiskaming district. While, however, outcrops of granite or gneiss to which the name Laurentian is strictly applicable are not found near the mines, certain pebbles and boulders in the conglomerates of the silver areas have been derived from the Laurentian. Brief mention may therefore be made of the character and relationships of these.

The Laurentian occupies large areas in the region in which the silver-cobalt mines are found. Rocks of this age, for example, outcrop almost continuously for fifty miles or more along the railway between North Bay and Doherty station. They consist characteristically of grey granite and gneiss, with alternate dark and light colored bands.

From a study of the relations of the Laurentian and Keewatin along the railway, to which reference has just been made, it appeared to Mr. Cyril W. Knight and the writer that the well-banded gneiss owes its composition and structure to the inclusions of fragments or masses of Keewatin in the intrusive granite, which have been squeezed or drawn out.* Near contacts large masses of Keewatin are enclosed in the granite. Farther away the inclusions are smaller and have been more readily squeezed, giving to the gneiss its characteristic banded or ribbon-like structure. Both the granite and gneiss are frequently cut by dikes of pink granite or pegmatite, many of which are narrow.

No rocks with the characteristics of the Laurentian are known that are older than the Grenville series, the Laurentian intruding both this series and the Keewatin. The Temiskaming is the oldest fragmental series known in the region that is of post-Laurentian age. While both the Temiskaming and Cobalt series contain pebbles and boulders derived from the Laurentian, the former series has not been seen in contact with the Laurentian unless it be on the southwest arm of Rabbit lake, east of Temagami station, where steeply dipping beds of conglomerate and associated rocks rest on the eroded surface of a grey granite-gneiss (Fig. 27). A short distance to the south of Doherty station, on the west side of the railway, rocks of the Cobalt series lie on the granite near its contact with the Keewatin.

*Twentieth Report, Ontario Bureau of Mines, pages 280-284.

Fig. 27. Beds of conglomerate and other rocks dipping at a high angle, southwest arm of Rabbit Lake, east of Temagami.

THE TEMISKAMING SERIES

Distribution

The most important area of the Temiskaming series near Cobalt occurs a few miles to the southwest, west and northwest of Haileybury. Its distribution here is shown on the map (Fig. 28). In this area fine outcrops occur along the shore of lake Temiskaming, between Haileybury and New Liskeard. Small outcrops also occur at the southwest corner of Cross lake, and the northwest corner of Kirk lake. In all, the series occupies an area of three or four square miles adjacent to the productive silver area at Cobalt.

The series is prominent at Porcupine, where some of the gold deposits occur in it, and it is also found in the Gowganda area, on lake Abitibi, on the Quebec side of the interprovincial boundary and elsewhere throughout the region. From descriptions that have been published by various authors, it would appear that fragmental rocks of the Sudbury area, of the north shore of Lake Huron and at the mouth of Doré river, near Michipicoten Harbor, Lake Superior, are of the same age as the Temiskaming series. Fragmental rocks, called lower Huronian in Michigan, and intruded by granite, also appear to be comparable to this series. Probably also conglomerate and other fragmental rocks in southeastern Ontario, known as the Hastings series, should be correlated with the Temiskaming (*See* part 2, Vol. XXII, Ont. Bur. Mines).

By some writers it has been thought that the series on the Quebec side of lake Temiskaming, to which the name Fabre was given, is of the same character and age as the Temiskaming series. But an examination of the Fabre exposures last autumn by Mr. Cyril W. Knight and the writer led to the opinion that the series had been named under a misapprehension. Two localities, where the Fabre has been described as occurring and showing unconformable relations to the younger Cobalt series, were found to contain only rocks of the Cobalt series. The lower rocks, to which the name Fabre was applied, are the slate-like greywacké of the Cobalt series, such as occurs in the cliff at what is known as the Little Silver mine on the Nipissing property and in numerous other localities. Did an unconformity exist at the points referred to, viz., on the shore south of Fabre wharf and at the second dam on Young's creek, it would be comparable to the unconformity between the slate-like greywacké and arkose in the township of Lorrain described by the writer. The name Fabre, as applied to these rocks, should, therefore, be discarded.

Structure

The conglomerates, greywackés and slates, of which the Temiskaming series is composed, generally are distinctly bedded, and the strata are everywhere seen to have been tilted up until they now rest in a vertical, or almost vertical, attitude. Cross-bedding has been noted in some of the greywackés. Along the shores of lake Temiskaming the strike is easterly, observations giving strikes of N. 60° to 70° E., and steep dips to the south. At the northwest corner of lot 8, in the second concession of Bucke, the strike is N. 20° W., with steep dips to the east. In various places the series is intersected by quartz stringers a few inches in width and a foot or more in length. (Figs. 27, 29.)

Relationships

In the Cobalt area the sediments of the Temiskaming series have not been seen in contact with the Keewatin greenstones or Laurentian granites and gneisses. At the southwest end of Cross lake, however, the conglomerates are in contact with the Keewatin iron formation and they hold numerous fragments of chert and red jaspilyte belonging to that formation. In parts of the conglomerate here many of the red jaspilyte pebbles are very angular, giving the rock at times an autoclastic appearance. It is probable that a contact between the conglomerates and Keewatin greenstones may be found, when further stripping is done, between the Temiskaming mine and Kirk

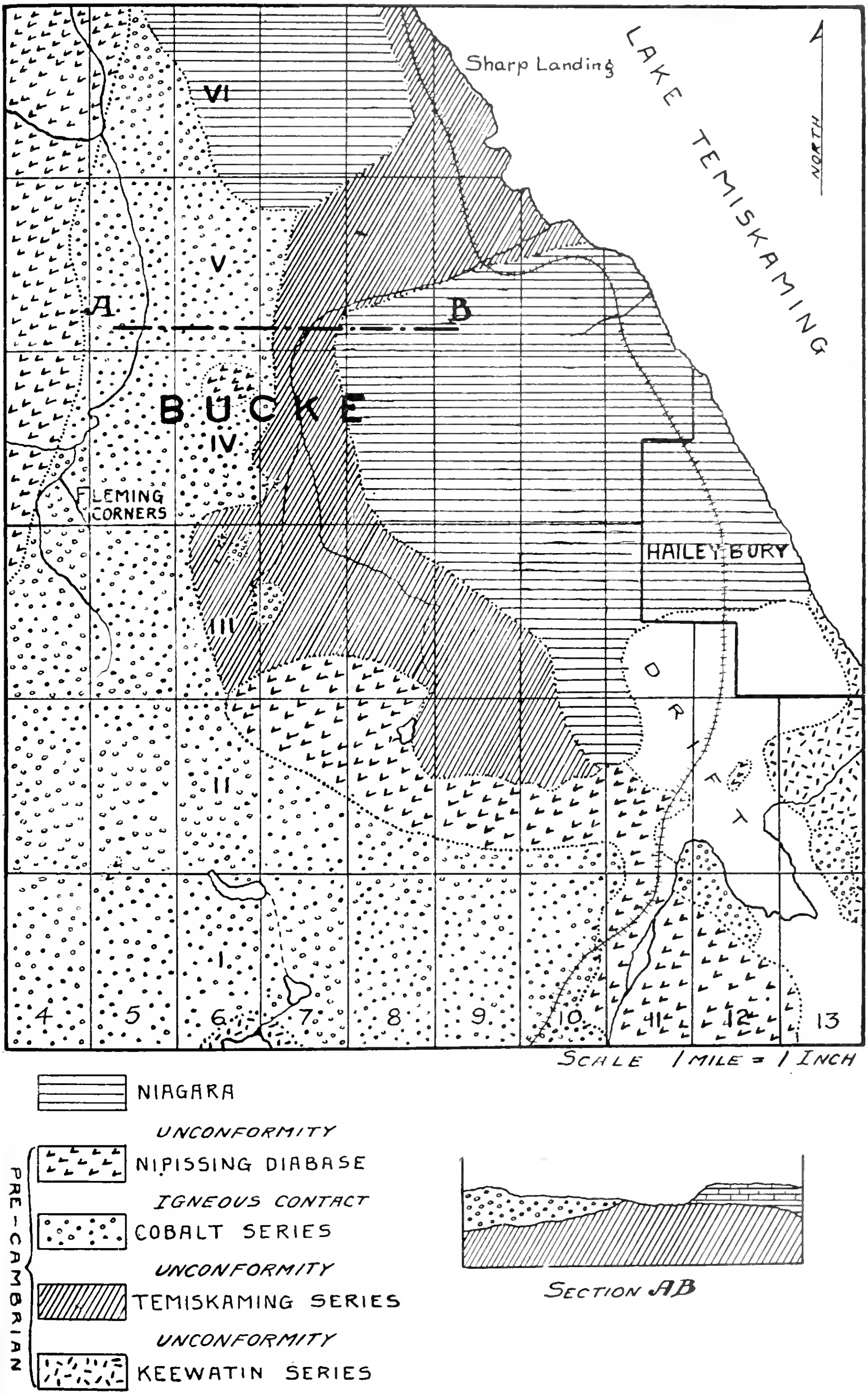

Fig. 28. Map showing distribution of Niagara limestone, Nipissing diabase, Cobalt, Temiskaming and Keewatin series. The centre of the map is about 3½ miles north of the town of Cobalt.

lake. Meantime, however, an unconformity is inferred to exist between these greenstones and the conglomerates, because the latter hold fragments of greenstone (basalt). The presence of diabase, acid porphyry and felsite pebbles in the conglomerate also clearly shows that the basement contains these rocks. For this reason the diabase dike at the Temiskaming mine, the diabase intrusive mass west of the Trethewey mine, the felsite on the northern shores of lake Sasaginaga, the acid porphyries at the Hargrave and Drummond mine, and the quartz-porphyry dike on the shores of lake Temiskaming below Haileybury, are all classed with the Keewatin series. It is to be noted, however, that these intrusives have not been found in contact with the Temiskaming conglomerate, and until they are their stratigraphic position will remain uncertain, especially since it is known that basic and acid intrusives invade the Lower Huronian sediments in the Vermilion Iron-Bearing district of the lake Superior region.

An unconformity is also inferred to exist between the Laurentian granites and gneisses and the Temiskaming sediments, because granite, syenite and granite gneiss pebbles are found in these sediments.

The Temiskaming series was invaded, first by lamporphyry dikes, and later by the great mass of Lorrain granite, which latter, near Kirk lake, has sometimes developed garnets in the adjacent rocks. Good contacts of the Lorrain granite and Temiskaming series are to be seen immediately south of the Temiskaming mine.

West of Haileybury about three miles an unconformity is exposed between the Temiskaming and Cobalt series. Here, at the southwest corner of lot 7, in the fourth concession of Bucke, the Cobalt conglomerate rests on the upturned edges of the Temiskaming greywacké, the latter showing distinct bedding. Nearby the older series is cut by lamprophyre dikes, which do not, however, invade the Cobalt sediments. In the same neighborhood there are several places where the two series are separated by a few feet of drift, but the discordance of the dips is so striking that there can be no doubt about the existence of the unconformity. At Fleming Corners the flat lying, slate-like greywackés of the Cobalt series are in marked contrast to the disturbed Temiskaming sediments one-half mile to the east.

Petrographic Characters

The Temiskaming series is composed of conglomerates, greywackés and slates. The conglomerates show a great variety of pebbles, including the following: basalt, diabase, green schist, pyroxene or hornblende-porphyry, quartz-porphyry, feldspar-porphyry, felsite, jaspilyte, grey, white and red cherts, grey granite, granite gneiss and coarse porphyritic syenite with crystals of feldspar one-half to one inch in length. Thin sections of fragments of the basalt pebbles from Cross and Kirk lakes show a feltwork of plagioclase rods, sometimes having flow textures; the plagioclase is set in a matrix of chloritic minerals, and one slide showed the plagioclase altered to chloritic material. The quartz and feldspar porphyry pebbles from Cross and Kirk lakes are made up of a fine-grained matrix of quartz and feldspar, with occasionally subordinate biotite; in this groundmass are set phenocrysts of feldspar, quartz and hornblende, the feldspar generally showing albite twinning lamellae. Two thin sections were examined of granite pebbles from the conglomerate between Haileybury and New Liskeard. They are made up of feldspar, quartz and hornblende; in one slide the feldspar occurs in phenocrysts, while in the other a porphyritic texture is lacking. A thin section from a granite gneiss pebble in the locality last mentioned shows the rock to be composed of quartz, feldspar and hornblende. These granite and granite gneiss pebbles are normal types.

The conglomerates have a white or grey color, due to the preponderance of light-colored pebbles, such as quartz and feldspar porphyry, felsites, etc. The size of the pebbles varies from tiny fragments to those which may be 15 inches or more in diameter.

Under the microscope the greywackés are seen to consist of angular fragments of quartz and feldspar set in a matrix of the same minerals in a state of fine division,

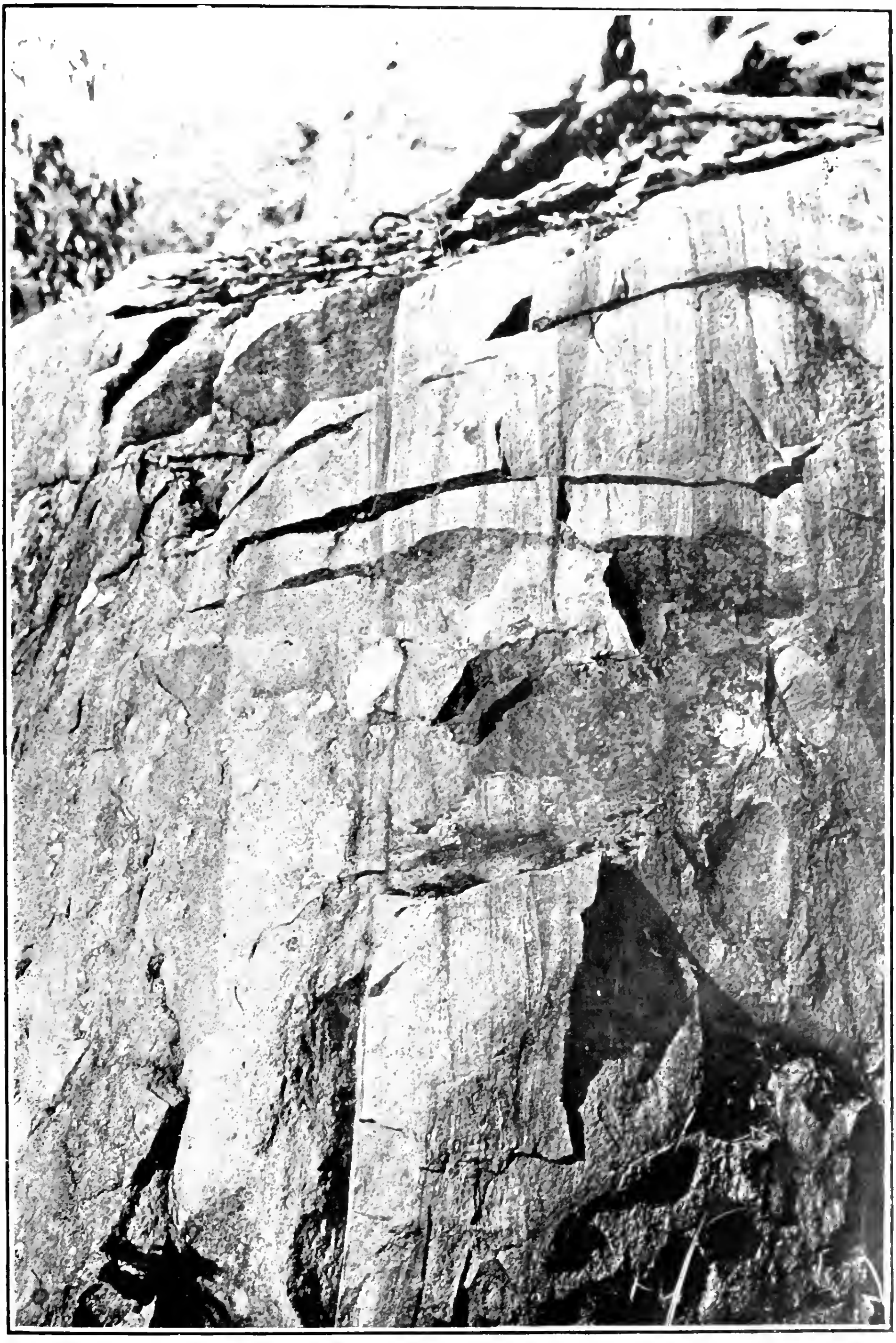

Fig. 29. Temiskaming series, with vertical dip, near shore of Lake Temiskaming between Haileybury and New Liskeard. Cross-bedding is shown in upper part of picture.

together with epidote, chlorite, hornblende and mica. In thin sections it is difficult to distinguish some of the greywackés from similar rocks in the Cobalt series, but on account of the disturbed condition of the Temiskaming series, and the comparatively undisturbed condition of the Cobalt series, they may be differentiated in the field. On the north part of lot 10, in the second concession of Bucke, the greywackés pass into very fine grained rusty rocks, which look like certain facies of iron formation.

Thin sections of the grey slates at Sharp Landing, lake Temiskaming, show them to be very fine-grained dense rocks, made up of opaque or almost opaque minerals, difficult to identify on account of their minute size. Iron formation outcrops at the Landing and the Temiskaming conglomerate contains pebbles and boulders of it.

At one or two places in the Gowganda area, there appears to be evidence of the extrusion of lavas contemporaneously with the deposition of the normal Temiskaming sediments.

The thickness of the Temiskaming series is not known, but it is believed to be great.

Midlothian Township

The rocks of the Temiskaming series in Midlothian and other townships to the north of Gowganda, and fifty miles or more west of Cobalt, have been described by Mr. J. G. McMillan as follows:*

" . . . comprises a series of fragmental rocks, consisting of conglomerates, greywackés and a few quartzites, and composed chiefly of worn down Keewatin materials. The conglomerates are sometimes rusty from the presence of included pebbles of cherty iron formation. The largest area of these sediments occurs about Kiahkusagainda lake, on the southwest side of Mount Sinclair. Many observations of the attitude of these beds showed that they dip at high angles, usually between 60 and 70 degrees, to the northeast or east-northeast, so that the present attitude of these beds is, at high angles, nearly transverse to the folds of the Keewatin.

. . . .

"Relatively, the rocks of this series form a very small portion of the present surface. In addition to the principal area in Midlothian township, there are isolated remnants or islands in the northeastern part of Bartlett and in McArthur townships. Other small areas probably occur, but are apt to escape notice, and are not easy to distinguish from brecciated members of the Keewatin.

"Sedimentary beds of this series, dipping at angles of from 55 to 85 degrees, outcrop in the vincinity of Kiahkusagainda lake for a width of over two miles. This would indicate a thickness of at least 7,000 feet." (Fig. 30).

Temiskaming Series at Porcupine

Concerning the Temiskaming series in the vicinity of Porcupine, Mr. A. G. Burrows says:†

"At Porcupine the Temiskaming series is of great economic value, since several important [gold] veins have been found in it. The largest area of these fragmental rocks stretches from the Dome mine in a northeast direction for about ten miles. It consists of a series of slate, quartzite and conglomerate which has generally been greatly disturbed. The beds have been highly tilted, dipping at angles from 70 degrees to vertical. A secondary cleavage has been developed in many parts, and the rocks have been rendered quite schistose. The general direction of the strike is from N.E.-S.W. to E.-W. In this respect the series is related to the Keewatin, which has a corresponding strike. It is evident that much of the deformation of the Keewatin and Temiskaming was post-Temiskaming.

"The sediments at the Dome have been greatly altered to schists. Similar rocks around Three Nations lake have been less altered, and, except for a high dip, greatly resemble the Cobalt series.

*Report on the Geology along the T. & N. O. Railway trial line between Gowganda and Porcupine, with map, Toronto, 1912.

†21st Report Ontario Bureau of Mines, Part I., pages 219 *et seq.*

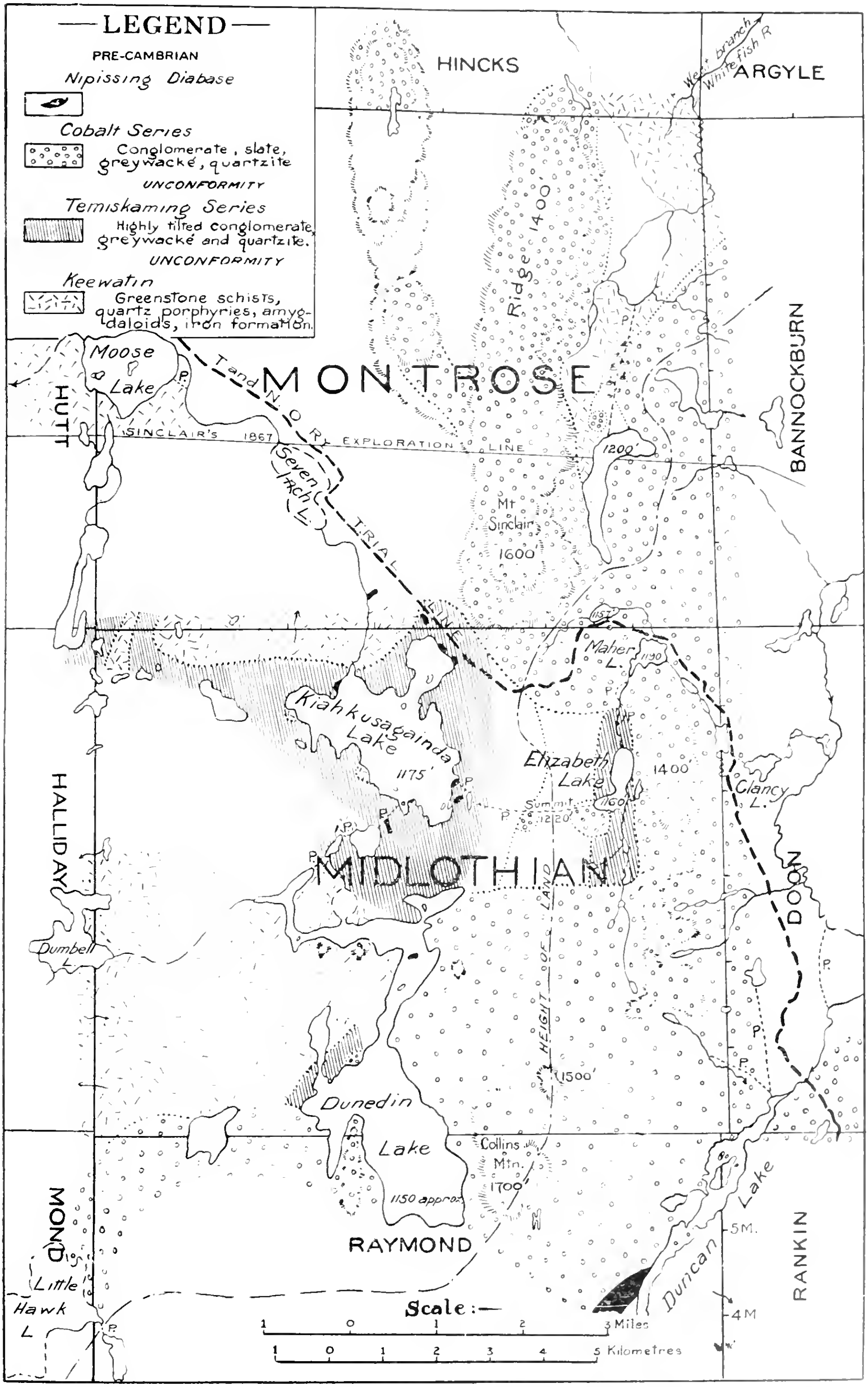

Fig. 30. Temiskaming and other series of rocks in Midlothian and adjoining townships.

"The succession of Temiskaming strata is well shown at the property of the Three Nations Mining Company on lot 5 in the fifth concession of Whitney. Along the line between the fifth and sixth concessions very much altered Keewatin rocks, now largely serpentine and rusty carbonate, are exposed. The contact with the Temiskaming conglomerate practically follows this line. At the base of the conglomerate are numerous fragments of rusty weathering Keewatin rocks: while farther to the south there are numerous pebbles of acid rocks, including the quartz-porphyry, felsite, etc. The conglomerate is succeeded by a narrow band of fine-grained black slate, which splits in very thin layers. Succeeding the slate is a greywacké which becomes coarser toward the south. About half a mile south of the concession line the rock is quite coarse-grained, and may be called an arkose-like quartzite. Throughout the Temiskaming series there is considerable carbonate, and many samples effervesce briskly with acid.

"It should be noted that no granite pebbles were found in the conglomerate. It is believed that the series was laid down when the surface rocks were largely volcanics, and that the intrusion of at least part of the granite came after the deposition of the Temiskaming, but prior to the Cobalt series.

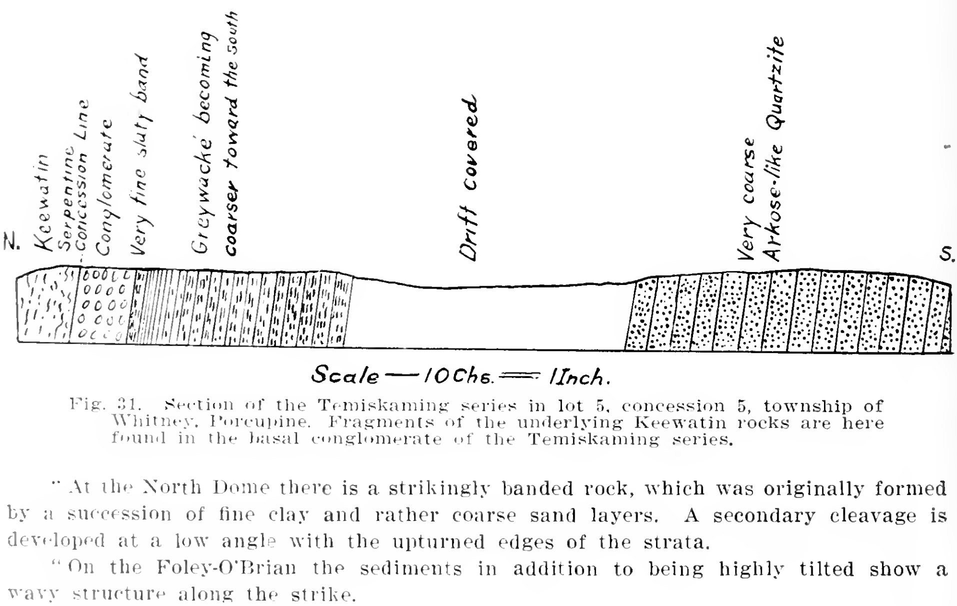

Fig. 31. Section of the Temiskaming series in lot 5, concession 5, township of Whitney, Porcupine. Fragments of the underlying Keewatin rocks are here found in the basal conglomerate of the Temiskaming series.

"At the North Dome there is a strikingly banded rock, which was originally formed by a succession of fine clay and rather coarse sand layers. A secondary cleavage is developed at a low angle with the upturned edges of the strata.

"On the Foley-O'Brian the sediments in addition to being highly tilted show a wavy structure along the strike.

"At the Dome property, in contact with large quartz masses, is a conglomerate which is likely basal. On the weathered surface the included fragments of porphyry, greenstone, schist, etc., are conspicuous, but in freshly broken pieces the conglomeratic character is easily overlooked, since the rock breaks in prismatic blocks resembling schist. The included pebbles are frequently drawn out in the direction of the schistosity. A thin section of greywacké from a mile west of the north end of Porcupine lake shows angular fragments of quartz and feldspar, together with sericite and other secondary minerals.

"Greywacké, with strike east and west and dip 85° north, occurs on the northeast shore of Night Hawk lake. In the greywacké are thin bands of conglomerate containing pebbles of dark green Keewatin rock, numerous quartz pebbles and some felsite. Some of the pebbles are six inches in diameter. A sample of the greywacké is seen under the microscope to consist of angular fragments of quartz and feldspar, with finer particles of the same material and chlorite, sericite and limonite.

"Altered sedimentary rocks outcrop at Wawaitin falls on the Mattagami river. These rocks have been greatly metamorphosed, but conglomerate, slate and quartzite

can be recognized. Some rusty bands of carbonate occur with the sediments. Similar rocks occur in Bristol township and at several points along the Mattagami river below Wawaitin falls. These rocks were formerly classed with the Keewatin, but from a similarity to the sedimentary rocks in Tisdale they are now grouped with the Temiskaming.

"On Red Sucker creek near Wawaitin falls at the third rock exposure from the Mattagami river there is a fresh looking greywacké which greatly resembles Huronian greywacké at Cobalt. The rock consists largely of quartz and feldspar, with some bits of rock like quartz-porphyry, in a cement of finer material consisting of quartz, feldspar, sericite, etc.

Fig. 32. Interbanded quartzite and slate of the Temiskaming series, showing secondary cleavage, North Dome mine, Porcupine.

Cobalt Series at Porcupine

"The younger series of sediments has been observed only in small volume on the south boundary of Langmuir. Here there is a typical undisturbed boulder conglomerate, very similar to the Cobalt conglomerate. It contains numerous pebbles and boulders of red hornblende and biotite granite, and rests unconformably on a Keewatin greenstone. Fragments of Keewatin occur at the base of the conglomerate."

ACID AND BASIC INTRUSIVES INTO THE TEMISKAMING SERIES

Under this heading are described the Lorrain granite and certain lamprophyre dikes, which have been found to penetrate the Temiskaming sediments. As has been said on a preceding page, other dikes that are provisionally classed with the Keewatin may intrude the Temiskaming series, but contacts have not been observed.

The Lorrain Granite

The distribution of the Lorrain granite is shown on the map of Cobalt, scale one mile to an inch. The rock is a coarse-grained, biotite granite, with a characteristic pink color. At Kirk lake it invades the Keewatin greenstone, the Keewatin iron formation (Grenville series), the Temiskaming sediments and the lamprophyre dikes. Whether some of the quartz and feldspar prophyries, described under the Keewatin series, are genetically connected with the Lorrain granite is not as yet known. The granite is overlain unconformably by the Cobalt series. Its relative age is therefore accurately known. Where it invades the adjacent formations it sends out in every direction many fine-to-medium-grained aplite dikes. In hand specimens these dikes are similar to some of the aplites which are the end phase of the Nipissing diabase. The latter dikes, however, contain only small quantities of potash, while the granite aplites at Kirk lake have normal percentages of soda and potash, as will be seen from the analyses given below. The intrusion of the Lorrain granite was probably the means whereby the Temiskaming sediments were tilted up into their present more or less vertical position. Near the contact the intrusion has sometimes developed garnets in the adjacent rocks.

Analysis No. 1, given below, is from the coarse-grained parts of the granite, while No. 2 is from the aplite dikes a few inches in diameter. In each case about a dozen specimens were taken in order to arrive at average results.

	1	2
SiO_2	71.86	76.03
FeO	2.34	1.29
Fe_2O_3	1.73	1.44
Al_2O_3	15.11	13.02
CaO	.51	.15
MgO	.43	.16
Na_2O	3.70	3.68
K_2O	3.48	3.74
H_2O	1.22	.96
	100.38	100.47

While the Lorrain granite has been intruded by the Nipissing diabase, silver-cobalt deposits of importance have not been found in it. That silver is readily deposited on the surfaces of or in cracks in the granite is shown by the occurrence of this metal in veinlets which penetrate granite boulders in the Cobalt series, in the vicinity of the veins at the Coniagas and Trethewey mines. Certain dikes from the granite penetrate the Keewatin in the lower workings of the Temiskaming mine and are cut through by the vein. The granite is here coated with silver.

Lamprophyre and Other Basic Dikes

Distribution

The dikes included under the general term lamprophyre are for the most part characterized by the prominence of hornblende, biotite or augite. They were first observed in the summer of 1906 on the west shore of Peterson lake. A hydraulic plant had been installed here for prospecting purposes by the Nipissing Mining Company,

and the soil on the hill facing the lake had been washed from the smooth glaciated rock surface, revealing several of these dikes. Since that year many others have been found, not only on the surface but also in the underground workings of several of the mines. Considerable trenching has been done at the southwest end of Cross lake and the northwest corner of Kirk lake, and many of the lamprophyre dikes have thus been uncovered in these areas. On the steep northwest face of the hill at the McKinley-Darragh a lamprophyre dike is well exposed. The Keewatin greenstones south of Haileybury, along the shore of lake Temiskaming, are likewise cut by these dikes, as are also the Temiskaming series of conglomerates and greywackés between Haileybury and New Liskeard. Again, about three miles west of Haileybury, near the main road, on lots 6 and 7 in the third and fourth concessions of the township of Bucke, there are many occurrences of the dikes, intruding the Temiskaming sediments. In the underground workings of the McKinley-Darragh, Little Nipissing, Kerr Lake and O'Brien mines the lamprophyres have also been met with. Other localities are known in the Cobalt area, and it is evident that these rocks are of common occurrence.

Certain lamprophyre dikes, *e.g.*, on the Nipissing property to the west of Peterson lake, contain rounded inclusions of the wall rock, and thus have the appearance of conglomerate.

Some of the mine operators at Cobalt are of the opinion that lamprophyre dikes, representing lines of weakness, in a few cases had an influence in promoting the fracturing of the rocks which gave rise to the fissures and cracks now occupied by cobalt-silver veins. It is interesting to note that veins are associated with similar dikes, kersantite, in the Saxon area, Annaberg, a description of which, with map, is given on a following page.

PETROGRAPHIC CHARACTER

It is possible that the lamprophyres include the following well-known types: minette, kersantite, vogesite and camptonite. It has, however, been considered sufficient to distinguish the rocks according to the prominence of the ferro-magnesian mineral present, so that the terms mica-, hornblende-, and augite-lamprophyre are here used. The dikes vary in width from about a foot to twenty feet or more. While they are

Fig. 33.—From photomicrograph of thin section of hornblende-lamprophyre dike cutting, Keewatin, on west shore of Peterson lake, Nipissing mine.

somewhat disturbed, and in some cases much decomposed, they are, nevertheless, generally massive rather than schistose, and still preserve in many instances their original textures. The rocks vary in grain from fine to coarse, the phenocrysts of pyroxene sometimes having a length of one-quarter of an inch or more in the coarser varieties, though this is uncommon. The minerals occurrring are the following: hornblende,

biotite, augite, feldspar, quartz, apatite and the iron ores. Of these, hornblende is, perhaps, the most commonly occurring of the ferro-magnesian minerals, but biotite is generally present and sometimes predominates over the hornblende. The mica is a brown pleochroic variety, occurring in hexagonal flakes, and it is frequently bleached. Augite does not occur as abundantly as hornblende; it has altered to uralite in some cases. The feldspar, which is with or without albite twinning lamellae, has not been seen to occur in phenocrysts. Quartz is always subordinate, and occurs alone or in micrographic intergrowth with a feldspar. In some of the thin sections apatite was found to occur as an abundant accessory, in long rods large enough to be readily recognized.

Twenty-eight thin sections of the lamprophyres have been examined, and the hornblende variety was found to be most prevalent, with biotite more common than the augite type. Hornblende-lamprophyre occurs near the hydraulic plant on the west shore of Peterson lake; mica-lamprophyre occurs at Kirk lake, while a good example of the augite variety is found on the steep northwest face of the hill at the McKinley-Darragh mine.

RELATION TO ADJACENT FORMATIONS

The stratigraphic position of the lamprophyres is known with much exactness. They intrude the Keewatin and Temiskaming series, but are older than the Lorrain granite and the Cobalt series. The dikes may be seen cutting the Keewatin rocks at the McKinley-Darragh, at the Nipissing, on the shore of lake Temiskaming below Haileybury, and at other places. The Temiskaming series is cut by these dikes at Kirk lake, at the southwest end of Cross lake, along the shores of lake Temiskaming between Haileybury and New Liskeard, and in other areas. Between the northwest corner of Kirk lake and the Temiskaming mine apophyses of the Lorrain granite cut the lamprophyre dikes, proving the latter are older than the granite. Moreover, the lamprophyres have never been found invading the Cobalt series, but, on the contrary, large boulders resembling the lamprophyres occur in the conglomerate of this series. It is possible that certain basic intrusives which cut the Keewatin rocks are of about the same age as the lamprophyres, but until they are seen in contact with the Temiskaming series it is not possible to prove this assumption. For instance, the diabase west of the Trethewey and Coniagas mines, the dolerite at the Argentite property, and the diabase dike at the Temiskaming mine, may all belong stratigraphically with the lamprophyres. These rocks are described in other parts of the report. If this assumption is correct, it agrees with the relationship of certain diabases and basalts in the Vermilion iron-bearing district of the Lake Superior region. In this district diabases and basalts cut the Lower Huronian but not the Upper Huronian. It is also of interest to note that in the Lake Superior region lamprophyre dikes occur, intruding the Lower but not the Upper Huronian sediments. These dikes are described by Clements as composed of various combinations of plagioclase and orthoclase, with biotite, hornblende, augite, and iron oxide, hornblende and augite being the predominant dark silicates. Kersantites, vogesites and probably camptonites occur in that district.

THE COBALT SERIES

The age relations of this series of fragmental rocks are shown in the table on page 48.

Since eighty per cent. or more of the ore mined at Cobalt has come from veins, or parts of veins, that are found in this series, it is the most important, from an economic point of view, of the rock groups of the area. Hence the name given to it is appropriate. The series also presents many other interesting features.

Nomenclature in Former Editions of this Report

Since the members of the Cobalt series—greywacké, quartzite and conglomerate—in the productive part of the Cobalt area proper are the lowest of the fragmental rocks, resting as they do directly on the eroded surface of the Keewatin, and since their age relation to the rocks of the classic Huronian area of the north shore of lake Huron is not yet known, it was thought best to speak of them as the Lower Huronian of the Cobalt area. In the former editions of this report, and on the colored maps, they are thus, provisionally, called Lower Huronian or Huronian, the name Cobalt series being applied to them only in a general way. Boulders of certain fragmental material in the conglomerate at Cobalt, and others of like character in the conglomerate of Gowganda, described by Mr. W. H. Collins,* together with the description of a sedimentary series including conglomerate, invaded by granite, at lake Abitibi, by Mr. M. B. Baker,† and to the east of the Quebec boundary by Mr. Morley E. Wilson,‡ showed that in the region there is an older sedimentary series than that at Cobalt. Moreover, Drs. Barlow and Young, in their report and map on the Lake Temagami area in 1904, describe a quartzite series on Rabbit lake which they call Keewatin quartzite, and place lower in the geological column than the conglomerate and other fragmental rocks in which are found the cobalt-silver deposits. In view of these facts the term Lower Huronian, as stated in former editions of this report and in the notes accompanying the maps, was used only provisionally. It seemed best to avoid local names, which might be more confusing to those interested in mining rather than in the more scientific aspects of geology.

The development of Porcupine led to the mapping of that area in detail, and has shown that a series of fragmental rocks, older than that in which the cobalt-silver ores are found, occurs in much greater volume than does the series which is characteristic of Cobalt. The older series of fragmental rocks, occurring to the north of Gowganda, in Midlothian township, has been described and mapped by Mr. J. G. McMillan,§ and has been found to the south of this area by Mr. R. B. Stewart. As shown on a preceding page, the older series of rocks also occurs adjacent to the productive part of the Cobalt area (Figs. 22, 28, 30).

It seemed necessary, therefore, in this edition of the report, to adopt local names for the two well developed series of pre-Cambrian sedimentary rocks of the region. Since the relations of neither the one nor the other to the rocks of the classic Huronian area are definitely known, it was decided for the present, at least, not to make use of the name Huronian. To the younger series that lie on the eroded surface of the Lorrain granite and other rocks, and contain many veins of rich cobalt silver ores, the name Cobalt is applied in this report. To the older series of fragmental rocks that are intruded by the Lorrain granite and are not of importance in the productive part of the cobalt-silver area, the name Temiskaming is given. This latter series is described in preceding pages.

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*Gowganda Min. Div. Report No. 1075, Geo. Sur., Can.
†18th Report, Ont. Bur. Mines, p. 275 *et seq.*
‡Geo. Sur. Can. No. 1064, pp. 18, 20.
§Report on Railway Trial Line between Gowganda and Porcupine, with Geological map. T. N. O. Railway Commission, Toronto, 1912.

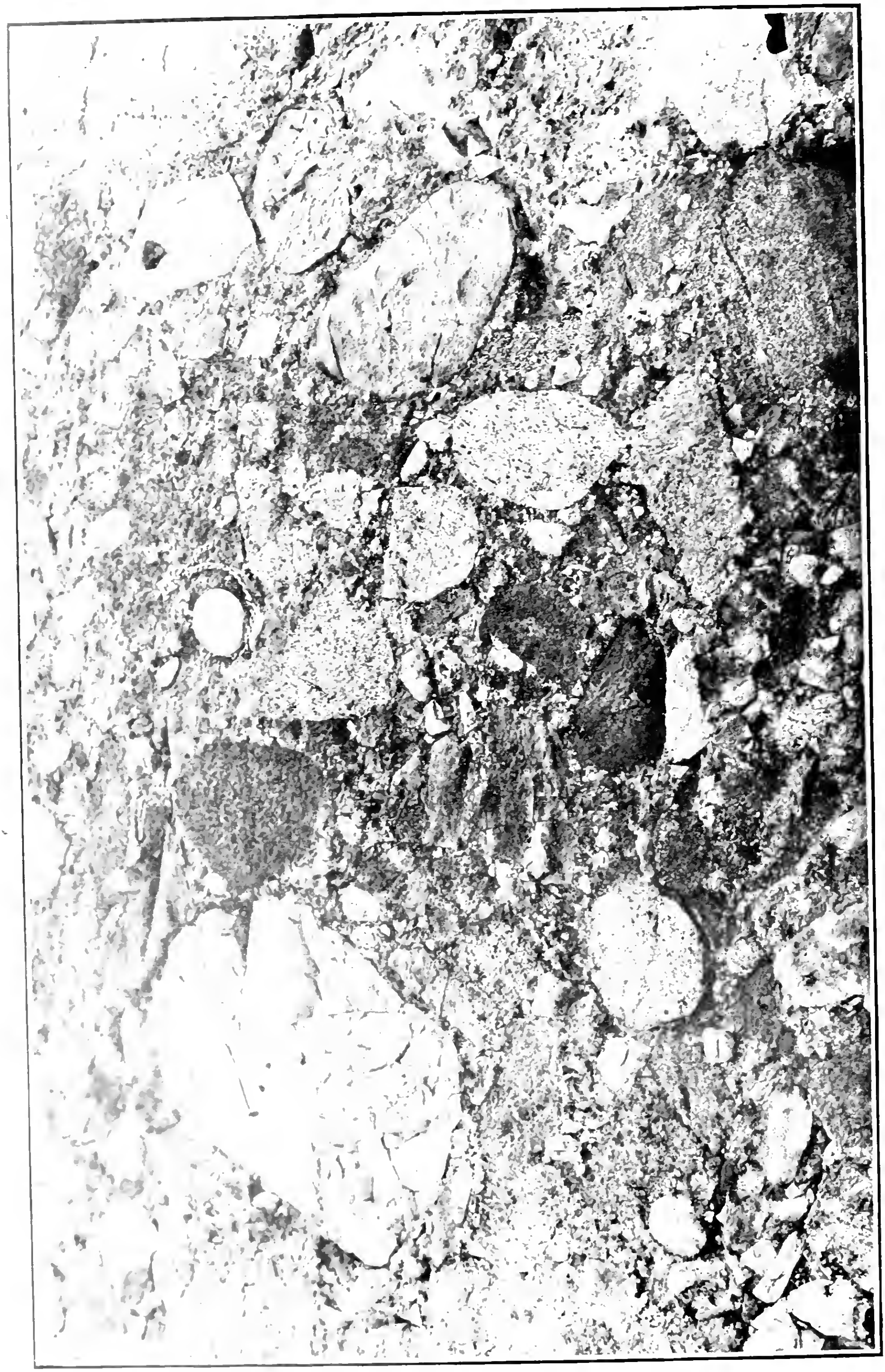

Fig. 34. Course boulder conglomerate of the Cobalt series, Cobalt.

Inclusion of Lorrain Arkose and Quartzite with Cobalt Series

The arkose and quartzite, to which the name Lorrain is applied in preceding editions of the report and on the colored maps, occurs in certain localities somewhat distinct from the conglomerate and other fragmental rocks of the productive part of the Cobalt area. For this reason and owing to the discovery of an unconformity between the arkose and the greywacké, such as that in which the veins are found at Cobalt, the Lorrain arkose and quartzite were named, provisionally, in former editions of the report, Middle Huronian. The unconformity referred to, as shown in following paragraphs, is not always present between the greywacké, or the rocks which are associated with it at Cobalt, and the arkose in the surrounding areas. In fact, there appears, judging from the observations of several workers in the region, to be in many cases a conformable sequence from the Cobalt conglomerate and greywacké upward through the Lorrain arkose and quartzite. It has thus been decided to group the Lorrain arkose and quartzite with the greywacké and conglomerate of the productive cobalt-silver area and to apply the name Cobalt series to all of these rocks; and to consider the unconformity, which has been observed at only two or three places, as not representing a great period of erosion.

The Lorrain arkose and quartzite, in so far as the cobalt-silver ores are concerned, have not been found to be of economic importance. Owing to this and to the fact that the arkose and quartzite frequently occupy tracts of country in which the lower members of the Cobalt series are practically absent, it is well, as far as possible, to distinguish on the maps, as has been done, the lower members from the upper (*See* colored maps of Cobalt, South Lorrain, Elk Lake and Gowganda, all on scale of 1 mile to 1 inch).

Erosion and Faulting

Erosion has left but remnants of the Cobalt series, which in a past age covered practically all the surface in a vast region in Ontario.

Faulting has played a part in the destruction. Elsewhere in this report great faults are mentioned which have profoundly affected Cobalt and the surrounding areas. Since, on the whole, the surface of the country, in the vicinity of Cobalt, does not now show great inequalities, it is seen that the rocks on the upthrow sides of the faults have been worn down until the surface stands at the level of the downthrow sides of the faults, the latter side also having been deeply eroded. The rocks of the Cobalt series have in many cases been worn completely off, exposing the Keewatin and other members of the older series.

While faulting has thus played its part in the destruction of the Cobalt series, and of course of older rocks as well, it has also, in some cases, had a protective effect. In certain areas, *e.g.*, along the west side of the fault in Cobalt lake, the Cobalt series on the downthrow side of the fault has a much greater thickness than it has on the east or upthrow side. In this lake the rocks on the downthrow side have not only been protected and preserved to a greater extent than have those on the opposite side of the line of fault, but the rich veins of cobalt-silver ore in them have also been thus conserved and have added to the length of the lives of the mines.

In other areas in the surrounding region certain of the highest hills are composed of rocks of the Cobalt series and appear, judging from their almost vertical faces and other features, to represent the upthrow sides of faults. Such hills are represented by Mt. Chemaniss, near the Quebec boundary, over forty miles north of Cobalt, and Mt. Sinclair, which lies about seventy-five miles to the northwest of Cobalt. Exposed in a face of the former hill are 550 feet of sediments of the Cobalt series, while in the latter there are about 300 feet. Both hills are referred to on following pages.

While faults are known that antedate the deposition of the Cobalt series, there are others which are much more recent. There are even small faults of post-Glacial age. The Silurian limestone in the township of Bucke, to the northwest of the town of New Liskeard, presents a striking cliff face, which was evidently produced by a

fault of considerable magnitude. This fault is of post-Niagara age, but just how recent it is cannot be determined. It is on a line that is a continuation of the remarkably straight western shore of lake Temiskaming.

The Cobalt series has thus been affected by faults at various periods. Were the region not covered to such an extent with glacial and recent deposits, without doubt a remarkable series of faults could be worked out.

Composition of the Cobalt Series

The series is wholly of fragmental origin, and contains rocks varying from those that are uniformly fine in grain to those that contain boulders several feet in diameter. The kinds of fragments composing these rocks are almost innumerable, representing as they do the erosive products from all the older pre-Cambrian series of the region—Keewatin, Laurentian, Temiskaming, Lorrain granite and intrusives of various ages. Naturally, fragments of the harder rocks and minerals have withstood better the destructive agencies to which they have been subjected, and the Cobalt series, especially the members of it that are coarser in grain, contains grains of feldspar and quartz, and pebbles and boulders of granite and other igneous representatives, in greater numbers than it does of minerals or rocks that weather or are abraded more readily. But representatives, as has already been said, of all the older rocks in the region are to be found in the form of pebbles or boulders as components of the Cobalt series.

Boulders Composed of Conglomerate

From the description of the Temiskaming series, on a preceding page, it will be seen that it, like the Cobalt series, consists of fragmental rocks, ranging from greywackés fine in grain to coarse conglomerates. Probably the most remarkable boulders in the conglomerate of the Cobalt series are those of conglomerate from the Temiskaming series (Fig. 35). If the latter series has furnished conglomerate boulders to the former, undoubtedly it has supplied pebbles or boulders of quartz and other minerals and rocks which once were constituents of its conglomerates, thus recalling the lines:

"The dust we tread upon was once alive."

Order of Deposition

The surface of the region, in the period immediately preceding the deposition of the Cobalt series, was uneven, and possessed in all probability higher hills and deeper valleys than those of the present surface. Having been laid down on such an uneven floor, the series cannot be expected to show the same thickness of sediments everywhere, even had a great period of erosion not elapsed between the deposition of the sediments and the present time. Moreover, it would be expected that there would be a considerable variation in the order of succession of the sediments from those that lie at the base to those that form the upper members. While such variation in the thickness of the members of the series, and in their order of deposition, has been observed, as is shown in the following table, still, while the thickness of the members differs from place to place, there is a pronounced definite order of deposition in the areas which have been studied by various workers throughout a wide region. The following quotations show that the order of succession of the members of the series in the surrounding areas is similar to that at Cobalt itself (Fig. 22, map).

Speaking of the Cobalt series at Larder lake, which lies about fifty miles north of Cobalt, Mr. Morley E. Wilson says: "An approximately regular succession can be recognized in the Huronian of this district. At the base is a conglomerate, which passes gradually upward through greywacké into arkose, which in its turn grades into an upper conglomerate."*

Of the series in the Montreal River area, forty miles northwest of Cobalt, Mr. W. H. Collins says: "The basal member is a conglomerate sometimes possessing a breccia

*Summary Report, Geo. Sur. Can. 1909, p. 176.

Fig. 35.—Boulder of conglomerate of the Temiskaming series enclosed in conglomerate of Cobalt series, at roadside, southwest corner lot 7, in the fourth concession of the township of Bucke.

structure and remarkable for the irregular distribution and frequently enormous size of its included boulders. This grades upward through greywacké into finely laminated slate and quartzite, followed in turn by an upper conglomerate."*

In Gowganda, fifty miles or more west of Cobalt, according to Mr. Collins, the same succession is observed: " . . . rocks are of clastic nature, consisting in ascending order of conglomerate, greywacké, slate and quartzite, which pass conformably into an upper conglomerate, while a granite-like, arkose member is believed, from its similarity to rocks of the same character in the Cobalt area, to be possibly of later age."**

Thickness

Having been subjected to erosion during most of the vast period that has elapsed since pre-Cambrian time, the uppermost members of the series have been removed, thus making an exact determination of the original thickness of the series impossible.

Moreover, complete sections of the thicker exposures of these rocks that occur in the region, such as those of Mount Sinclair and other hills in that vicinity, and Mount Chemaniss and other hills in the Larder lake area, are not obtainable, the basal member, conglomerate, of the series either being not exposed or not completely so.

In the Cobalt area the writer estimated that the series at some points may now have a thickness of at least 500 feet.

Mt. Sinclair, in the township of Midlothian, north of Gowganda, according to Mr. J. G. McMillan, has a thickness of these rocks of 300 feet, passing from the conglomerate, the lower part of which is concealed, upward through greywacké, slate, and quartzite to conglomerate at the top.†

Mt. Chemaniss is described by Messrs. Parks and Bowen as having a thickness of 550 feet, the greywacké at the bottom passing upward through quartzite to conglomerate at the top.‡ Here the base of the section is concealed.

In all of the sections just mentioned, the Lorrain arkose and quartzite are absent.

The following table shows the thickness of the Cobalt series at several characteristic localities, and the nature of the sediments together with the order of deposition.

WENDIGO LAKE	LITTLE SILVER CLIFF (Cobalt)	MT. CHEMANISS	MT. SINCLAIR	MAPLE MOUNTAIN
Conglomerate *	Conglomerate (30 to 40 ft.)	Conglomerate (100 ft.)	Conglomerate *	Arkose and Quartzite (900 ft.) ***
Greywacke and Quartzite (26 ft.)				* * *
Quartzite (10 ft.)	Quartzite (15 ft.)	Quartzite (135 ft.)		* * *
Greywacke (54 ft.)	Greywacke (20 ft.)	Greywacke (315 ft.)	Greywacke (300 ft.)**	* * *
* * *	* * *	* * *	Conglomerate *	* * *
Total thickness 90 ft.	70 ft.	550 ft.	300 ft.	900 ft.

*Thickness not given. **Greywacke contains occasional beds of slate and quartzite. ***Base of section is not exposed.

The arkose and quartzite of Maple mountain, described on another page, are considered to represent the Lorrain or upper part of the Cobalt series. This mountain contains the greatest thickness of sediments known in the region.

As an example of a section where members of the series are absent may be cited the exposure on the shore of the bay, on the east side of lake Temiskaming, immediately south of Fabre wharf. Here the upper conglomerate lies on the surface of the well-banded greywacké. In the township of Lorrain, an outcrop, described in accompanying pages, consists of Lorrain arkose resting unconformably on the slate-like greywacké, the quartzite and upper conglomerate being absent.

*Idem, 1908, p. 117.

**Preliminary Report on Gowganda Mining Division, Geol. Sur. Can. 1909, No. 1075.

†Report on the Geology along T. N. O. Railway trial line between Gowganda and Porcupine. Toronto, 1912

‡Summary Report, Geol. Sur. Can., 1904, p. 220. 17th Report, Ontario Bureau of Mines, p. 11.

Underlying Surface

In the vicinity of Cobalt, in so far as observation has gone, the Cobalt series always rests on a weathered surface of one or other of the older series of rocks. Most commonly the underlying series is the Keewatin, as rocks of this age are more widespread in the productive part of the area than are the other pre-Cobalt series. No surface that has the appearance of having been produced by glaciation or rendered smooth by other means is known beneath the Cobalt series in the vicinity of Cobalt.

Where the rocks of the Cobalt series rest on the greenstones or other easily decomposed members of the Keewatin there is a gradual transition from the non-

Fig. 36.—Contact on the shore of Lake Temiskaming between the Keewatin and Cobalt series. The breccia of the Cobalt series rests on the Keewatin rock, from which it was derived. The light-colored fragments of the breccia are set in a dark ground mass. Lot 15 in the second concession of Bucke.

disintegrated rock upward into the distinctly fragmental member of the Cobalt series. The disintegrated material on the surface of the Keewatin has been recemented and consolidated, or, in other words, recomposed. It is impossible at certain contacts, without the examination of thin sections under the microscope, to distinguish the recomposed material from the underlying massive igneous rock.

Something the same may be said of the contact between the upper members of the Cobalt series, the Lorrain arkose, and the Lorrain granite. In the township from which the name of these rocks is derived, arkose lies on the weathered surface of the granite, there being a gradual passage from the undecomposed rock upward into the arkose.

At the base of the Cobalt series there is the recomposed material described in the preceding paragraphs with, typically, conglomerate or breccia, the most of the fragments of which can be seen to have originated in place. A striking example of the origination *in situ* of such material is to be seen on the shore of lake Temiskaming, on the extreme north end of lot 15 in the first concession of the township of Bucke, a couple of miles south of Haileybury. Here, as the geological map, scale 1 mile to 1 inch, shows, the Cobalt series forms a contact with the Keewatin. At the contact the Keewatin consists of greenstone, or basalt, and a dike of feldspar-porphyry. That the conglomerate and breccia of the Cobalt series, here resting on the Keewatin, has for the most part at least, originated *in situ* is shown by the fact that it contains fragments of various sizes of the porphyry dike. These fragments range in form from angular to sub-angular and rounded (Fig. 36). Both the greenstone and the porphyry, but more especially the latter, show characteristic torsion cracks, Fig. 25, being from a photograph of these rocks.

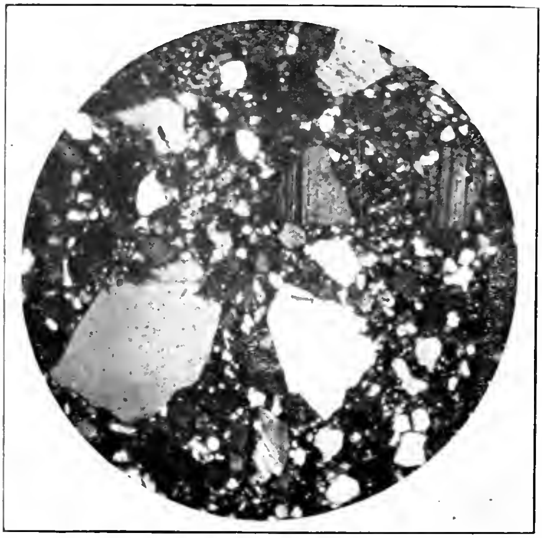

Fig. 37.—Photomicrograph of greywacké of Cobalt series.

This contact and others in the district, between the Cobalt series and the older rocks, have a striking resemblance to those which have been described as existing between members of the pre-Cambrian, Torridonian and the older Lewisian, of the Northwest Highlands of Scotland. "The observer may climb one of these Archæan hills, following the boundary between the Lewisian and the younger formation, and note, step by step, how the sub-angular fragments of hornblende-schist that fell from the pre-Torridonian crags are intercalated in the grits and sandstones, thus indicating the slow submergence of the old land-surface beneath the waters of Torridonian time."*

"The basal breccias which often flank the buried mountains are, as already explained, of the nature of scree material. They consist of fragments of the local rocks embedded in a sandstone matrix. The conglomerates, on the other hand, are probably torrential deposits brought down from a district very different in geological structure from that of the area in which the Lewisian gneiss occurs."†

*The Geological Structure of the North-West Highlands of Scotland, p. 4. Memoir of the Geological Survey of Great Britain.

†Idem, pp. 286-7.

Slate-like Greywacke

Normally, the basal conglomerate and breccia pass gradually upwards into fine-grained, delicately banded, slate-like greywacké (Fig. 37). The components of the greywacké are so fine in grain that they cannot be distinguished except by examination of thin sections under the microscope. When thus examined they are found to consist, for the most part, of angular fragments of quartz and feldspar, which is usually quite fresh and undecomposed (Fig. 37). The feldspar consists of orthoclase, microcline and the more acidic soda-lime varieties. Grains of glassy volcanic rocks, and of iron ore and other material have also been observed. Chlorite and other decomposition products are present. Under the microscope certain thin sections of the greywacké resemble volcanic ash. It has not been proved, however, that there was contemporaneous volcanic activity.

Typically, the slate-like greywacké has a greenish or greyish color, but in certain localities the color of the rock is distinctly reddish. The latter color is not found in the greywacké of the productive part of the Cobalt area proper, but reddish grey-

Fig. 38.—Fragments of slate-like greywacké, cemented together by light-colored arkose.

wacké lies both to the west and to the east, outcropping in the western half of Coleman township, near Latchford on the Montreal river, and at two or three points near the shores of lake Temiskaming.

The greywacké, like the other members of the Cobalt series, lies usually in an almost horizontal position. Ripple or wave marks are frequently seen on the surface of its beds, *e.g.*, in the cliff at the Little Silver mine on the Nipissing property. Mud cracks are occasionally present. While usually showing little evidence of disturbance, the greywacké is quite compact and does not split readily along the junction of many of the beds.

Normally, the greywacké passes upwards into quartzite, more or less impure, and the latter into conglomerate, but at times the quartzite is lacking and the greywacké is succeeded by conglomerate. Where the members of the series are complete, as at some points along the eastern shores of lake Temiskaming, the conglomerate appears to be succeeded without unconformity by what has been called the Lorrain arkose and quartzite, the latter of which is frequently interbanded with pebbly material.

At two or three places, however, where the upper members of the series, conglomerate or arkose, lie directly on the greywacké without the quartzite or other

Fig. 39.—Slate-like greywacké of the Cobalt series, resting in almost horizontal position, Nipissing mine, Cobalt.

intermediate member being present, the greywacké appears to have been eroded before the deposition of the overlying rock. On lot 4, in the twelfth concession of Lorrain township, a striking contact, and unconformity, between the lower slate-like greywacké and overlying arkose is to be seen. The surface of the dark colored greywacké has been broken into angular fragments, the spaces between which are filled in and cemented by the light colored arkose (Fig. 38). The feldspar grains in the arkose are remarkably fresh, some of them retaining the pink color characteristic of orthoclase or microcline.*

This unconformity, between the greywacké and arkose, should in all probability not be considered to represent a great time interval or period of erosion. To use a term that has been employed in other regions, it may be called an interformational unconformity.

The unconformity is the only one that has been observed between members of the Cobalt series in the Cobalt area proper or in the immediately surrounding areas. At one point near Obushkong lake in Gowganda, however, a similar unconformity has been observed between the greywacké and overlying conglomerate.

Where the thickest and most complete sections of the Cobalt series are found, *e.g.*, on the east shore of the northern part of lake Temiskaming, there appears to be no break in the series, the passage from the greywacké, quartzite and conglomerate below to the Lorrain arkose and quartzite above being unbroken.

Thickness of the Greywacke

The thickness of the more typical, delicately banded greywacké is variable. Usually, at the bottom of the series, greywacké forms the matrix of the lower conglomerate and breccia. On passing upward the coarse fragments disappear. In some places the greywacké has a thickness of only a few feet, but there are frequently thirty or forty feet or more exposed. (See preceding table of thickness of members of the Cobalt series).

Chemical Composition of Greywacke

The following table shows the composition of samples of the delicately banded greywacké from the Little Silver cliff on the Nipissing property at Cobalt. The analysis was made by Mr. A. G. Burrows.

ANALYSIS OF SLATE-LIKE GREYWACKE

	Per cent.
Silica	62.74
Alumina	16.94
Ferric oxide	5.07
Ferrous oxide	1.59
Lime	1.39
Magnesia	3.05
Soda and potash	6.07
Moisture	.36
Loss above 110 degrees	3.20
Total	100.41

*The contact on the lot mentioned was recently revisited by Messrs. Cyril W. Knight and A. G. Burrows, who are inclined to doubt the evidence of erosion, and to call the rock at the contact crush-breccia.

ANALYSIS OF BRECCIA

A sample of the breccia of medium grain, from the wall of La Rose vein, was found to be more basic in composition than the greywacké, as the following result of analysis shows:

	Per cent.
Silica	43.12
Alumina	19.74
Ferric oxide	5.72
Lime	5.40
Magnesia	7.48
Soda	4.50
Potash	1.75
Cobalt and nickel	.55
Loss on ignition	10.94
Arsenic	1.18
Total	100.38

The sample showed in places the greenish arsenate of nickel and also bright specks of a light colored mineral, evidently smaltite or chloanthite.

Fig. 40.—Columnar jointing perpendicular to the planes of bedding in slate-like greywacké. The structure is due to the effects of intrusive diabase on the slate. A section of a small column is on top of the larger one. Lot 15 in the first concession of Bucke.

Columnar Structure

Where trenches or open cuts have been excavated on certain veins, the greywacké is seen to have a well developed columnar structure, the columns being vertical. Such a structure in this rock is also well developed in the railway cut near the shore of Cobalt lake, a short distance south of the station.

The well banded greywacké-slate on the north part of lot 15, in the first concession

of Bucke, has this columnar structure very perfectly developed in it (Fig. 40). The columns here have a much smaller diameter than those just mentioned. They are developed at right angles to the bedding of the slate, which is almost flat-lying, and they are nearly as perfect in form as columns found in basalt. On this lot in Bucke the columns are developed at the contact of the slate with intrusive diabase. That columnar structures of this kind are not uncommon in fragmental rocks is seen from the following statement: "Contact with eruptive rocks has frequently produced a prismatic structure in the contiguous masses. Conspicuous illustrations of this change are displayed in sandstones through which dykes have risen. Independently of the lines of stratification, polygonal prisms, six inches or more in diameter, and several feet in length, starting from the face of the dyke, have been developed in the sandstone."*

Quartzite

Normally the slate-like greywacké is succeeded above by quartzite, more or less impure. In some places, however, the quartzite is absent, and the next member of the series, viz., conglomerate, rests directly on the greywacké.

The quartzite usually has no great thickness, frequently being only twenty or thirty feet, but in certain localities impure quartzite or greywacké that overlies the delicately banded greywacké has a much greater thickness.

At the Little Silver cliff, on the Nipissing property, the base of the Cobalt series is not exposed. Here there are fifteen or twenty feet of well-banded greywacké, overlying which there is about the same thickness of feldspathic quartzite. Above the latter are twenty or thirty feet of conglomerate (see Frontispiece). At times the quartzite is interbanded with greywacké.

Conglomerate

What may be called the second conglomerate, to distinguish it from the conglomerate and breccia that lie at the base of the well-banded greywacké, or in other words the conglomerate that overlies the quartzite, is one of the most interesting members of the Cobalt series. The great variety of pebbles and boulders that are found in this rock give to it an appearance that attracts attention. It contains boulders representing practically all of the numerous older rocks of the region. Whether it represents a glacial deposit, or whether it is of torrential or other origin, in the opinion of many observers, is undecided. Figs. 34, 35, 41, 42 illustrate the character of typical examples of this rock.

The conglomerate of the Cobalt series is distinguished from that of the Temiskaming series chiefly by the fact that pebbles and boulders of pink granite, rather coarse in grain, are characteristic of the former and not of the latter. This is owing to the fact that the granites of the region, that antedate the Temiskaming series, are typically grey in color, while the pebbles and boulders in the conglomerate of the Cobalt series have been derived from the pink colored Lorrain granite, which intruded the Temiskaming but is older than the Cobalt series.

Origin of the Conglomerate

In the first edition of this report, concerning the origin of the conglomerate it was said: "It is difficult to understand, for example, how certain large boulders of granite in the conglomerate, which forms part of the highest outcrops of the Lower Huronian (Cobalt series), have been carried so far from their parent masses. These large boulders are found over much of the district, and there are now no outcrops of granite in the neighborhood of many of them. . . . In the present state of our knowledge we have little warrant for claiming that the granite boulders, often two or three feet or more in diameter and distant a couple of miles from exposures of the rock, indicate glacial conditions during Lower Huronian times, although we have no proof to the contrary."†

*Geikie, Text-Book of Geology, p. 769.
†Fourteenth Report, Bureau of Mines, Ontario, Part II., p. 43.

Fig. 41.—Boulder conglomerate, Cobalt series, Drummond mine. The large boulder on the right hand side at the top is 30 inches in diameter.

A couple of years after this report was published Dr. A. P. Coleman, while on a visit to the Trethewey mine, discovered striated boulders in the conglomerate in an outcrop on this property† that have all the characteristics of those which are found in glacial deposits. Hence, Dr. Coleman, and other writers have decided that a certain part, at least, of the conglomerate of the Cobalt series is of glacial origin.

In the opinion of the present writer more evidence is required before the glacial origin can be accepted. Although for many years conglomerates similar to those of Cobalt have been studied over a vast extent of territory in northern Ontario, no glaciated surface on the rocks underlying this conglomerate has been discovered. During the last few years several workers in the Cobalt and surrounding areas have diligently searched for such a surface, but without success. The underlying rocks present, characteristically, a weathered surface, there being no sharp line of division between the underlying undecomposed, or non-disintegrated, rock and the overlying fragmental rock. The glacial origin of the Cobalt conglomerate cannot therefore be proved so clearly as it can for similar rocks in other parts of the world. The Dwyka of South Africa, for example, rests on rocks that frequently show undoubted evidence of having been smoothed by glaciers.

A glacial origin was at one time suggested for certain breccias or conglomerates in the Torridonian of the Northwestern Highlands of Scotland. In the report on that region, published a few years ago, this suggested theory of origin has been discarded.* "From the nature of the rocks it may be inferred that the conditions of deposit were probably those of a rapid accumulation in shallow water near a shore line, subject to violent currents and the influx of flood or stream-borne materials, with occasional intervals of quiescence during which the finer sediments were laid down. . . . In one instance, on the north side of Loch Maree, it has been observed that the blocks in the conglomerate have come from the hornblende-schist ridge of Ben Lair, and may have travelled a distance of three miles."

That surfaces on rocks resembling closely those produced by glaciers can be formed by other means is shown by the observations of Dr. E. O. Hovey.‡ In speaking of the accumulation of volcanic material on the side of Mt. Pelee, he says: "From time to time the coat of new material became water-soaked from the heavy tropical rains and slid down the mountain in more or less of a sheet avalanche. On the collecting ground of the steep upper cone, planation and grooving were not prominent, but on the middle ground of the Morne Saint Martin, where the force of the avalanches spent itself, planation and grooving were pronounced. In June, 1902, the striated surface of the old agglomerate, with here and there a heap of unassorted ash upon it, suggested closely the appearance of a regularly glaciated surface with its overburden of till."

Dr. Hovey says further: "Where the crevicing of the rock-mass has been favorable, the impact of stones hurtling down the stream bed has broken off chips from the bed rock, producing a good imitation of the 'chatter' marks made by a glacier."

If such surfaces are thus produced, undoubtedly the faces of pebbles and boulders in moving masses of rock are also grooved and striated in such a way as to be undistinguishable from those of glacial origin.

The, on the whole, definite order of deposition from breccia and conglomerate at the base upward through greywacké, quartzite and conglomerate, leaving out of consideration the overlying Lorrain arkose and quartzite, has the appearance of ordinary sedimentation and not that of deposition by glacial agency.

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†Am. Jr. Science, March, 1907. Journal of Geology, February-March, 1908.

*The Geological Structure of the North-West Highlands of Scotland, pp. 23 and 273. Memoirs of the Geological Survey of Great Britain, 1907.

‡Striation and V-shaped Valleys Produced by Other Than Glacial Action. Geol. Soc. Am., Vol. 20.

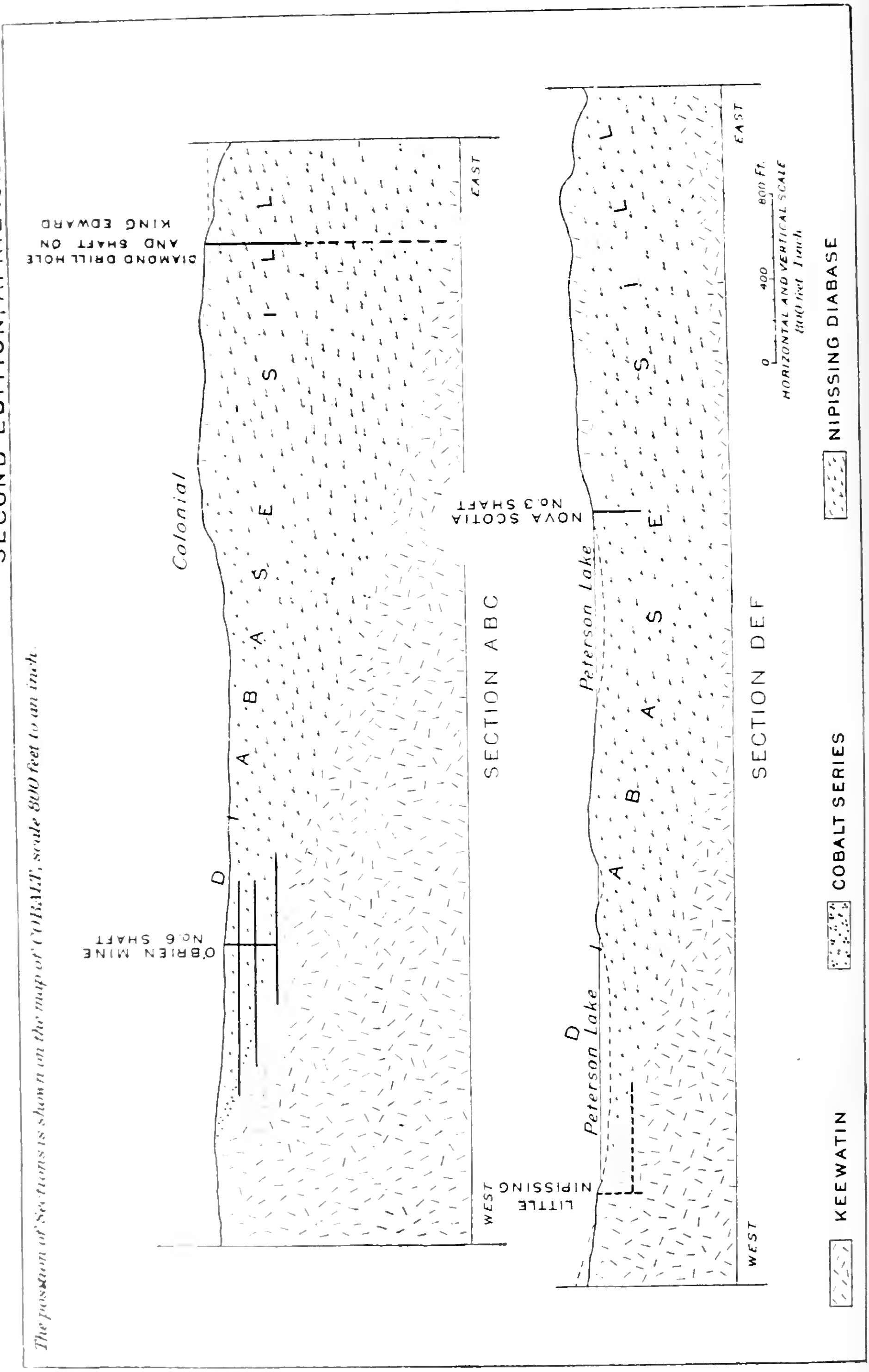
Fig. 42. [illegible] conglomerate of the Cobalt series, Cobalt.

Lorrain Arkose and Quartzite

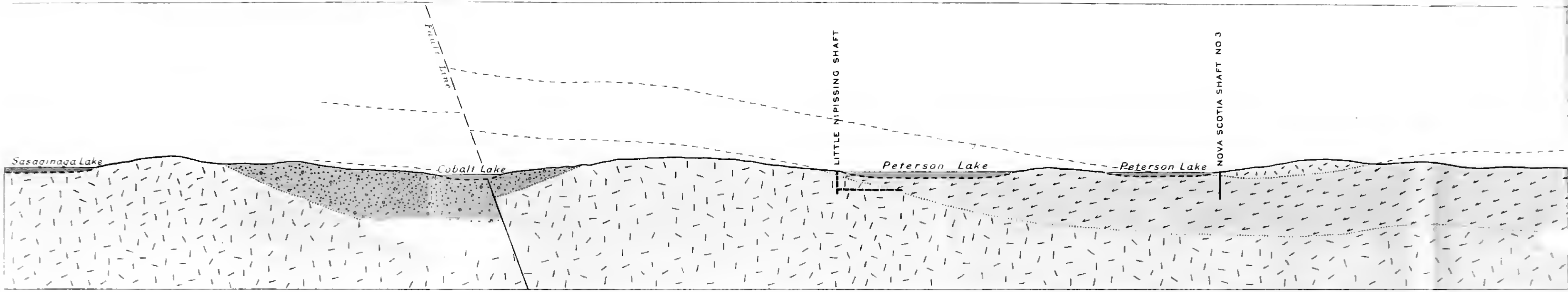
As explained on preceding pages the arkose and quartzite, to which the name Lorrain has been applied, are here grouped with the Cobalt series, and are considered to represent the upper members of the series. In two or three localities the arkose or quartzite has been found to be unconformable to the slate-like greywacké or other lower members of the series, but in other places there is no evidence of an erosion interval. Since, however, the arkose and quartzite in most of the areas that have been mapped tend to occur distinct from the lower members of the series they are distinguished on the maps, by a different color, from the latter.

Frequently the arkose is found on the surface of granite, *e.g.*, in the township of Lorrain, and is the decomposition product of the latter rock, there being a gradual passage from the undecomposed rock into the arkose. There is, moreover, a gradual passage upward from the arkose, first into impure quartzite, then into a purer quartzite and conglomerate, composed chiefly of quartz pebbles.

Fig. 42a.—Prospectors at Cobalt, May, 1904.



The position of Sections is shown on the map of COBALT, scale 800 feet to an inch.

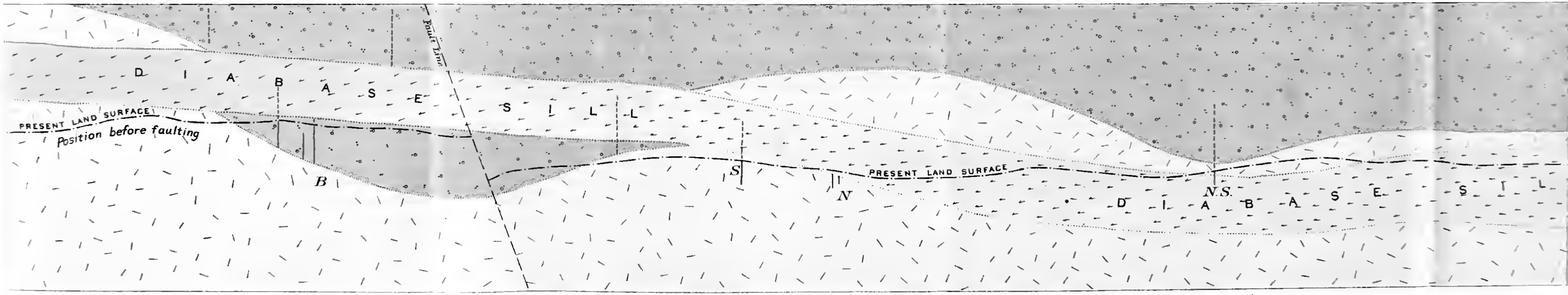


NOTE - The thickness of the diabase at the Nova Scotia is not known

GENERAL SECTION R.S.D.E.T.J.U.V. THROUGH COBALT

The position of this Section is shown on the map of COBALT

IDEAL RESTORATION OF ROCKS AND VEI



KEEWATIN LORRAIN GRANITE COBALT SERIES NIPISSING DIABASE

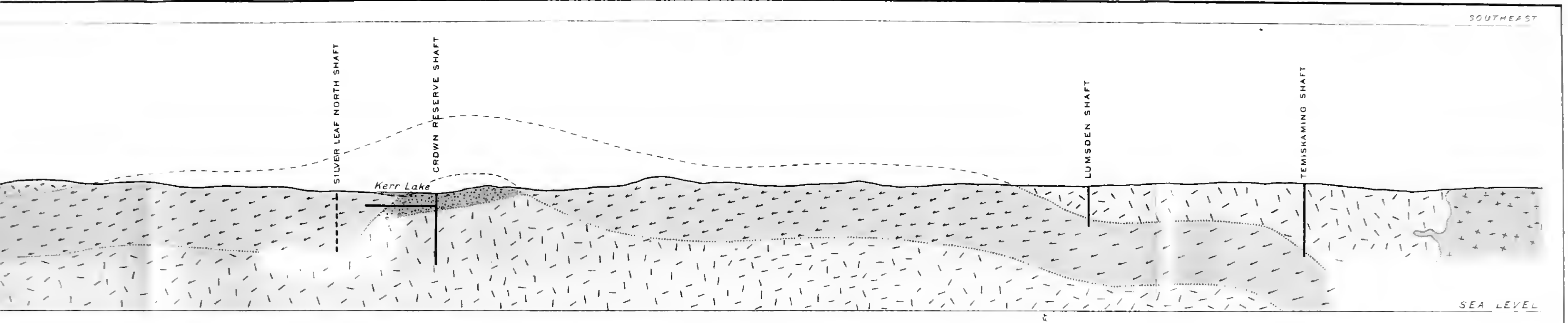
Silver Cobalt Veins are shown thus

Problematical Silver Cobalt Veins are shown thus

NOTE - The part below the present land surface is practically a reproduction of the general section. The fault line and original position of present land surface west of fault are shown for comparison of ideal with general section

To accompany Fourth Edition of Report by **WILLET G. MILLER**, *Provincial Geologist, on the Cobalt*

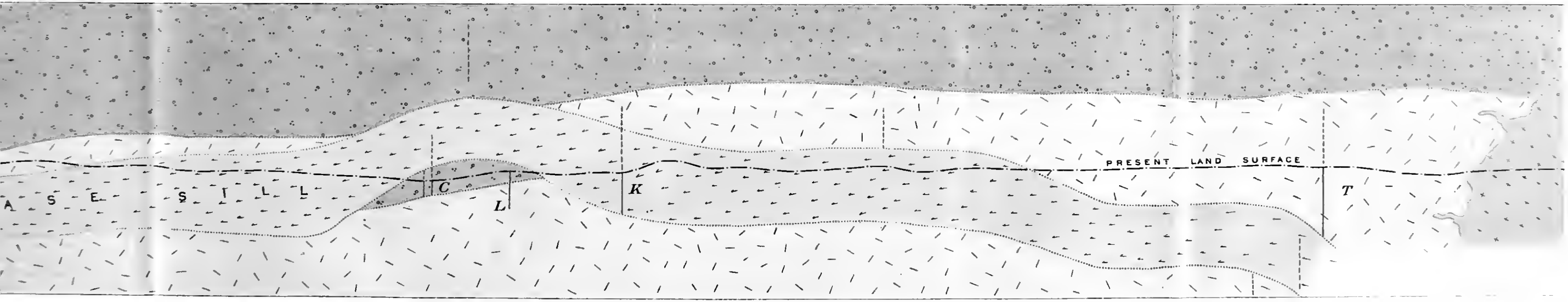
In Part II. of the Nineteenth Report of the Bureau of Mines



.T.J.U.V. THROUGH COBALT–LENGTH 4.53 MILES

Section is shown on the map COBALT, scale 800 feet to an inch.

ON OF ROCKS AND VEINS AT COBALT



Problematical Silver Cobalt Veins are shown thus | *B* Veins on Buffalo, Coniagas, etc. *N* - Little Nipissing Veins *S* - Vein No 26 on Nipissing *C* - Crown Reserve Veins *L* Lawson Veins *K* Vein No 3 Kerr Lake *T* Temiskaming Veins *N S* Nova Scotia Veins

T. G. MILLER, Provincial Geologist, on the Cobalt-Nickel Arsenides and Silver Deposits of Temiskaming
II of the Nineteenth Report of the Bureau of Mines, Ontario.

THE NIPISSING DIABASE*

I. STRUCTURAL RELATIONS OF THE SILL

The data embodied on the cross-sections (plates I. to VI.), that accompany this report, have been collected from time to time during the past eight years, and were compiled by Mr. Knight. It was recognized in 1904, from a study of surface conditions, that the diabase occurred in the form of a sill or sheet. Since that time much underground work has been accomplished, which has shown more clearly the form and character of the sill. The cross-sections show that the sill rests at times almost horizontally on the underlying rocks, as may be seen, for instance, in the section through Mount Diabase—plate II, section G. H. In the Kerr lake area, however, it inclines steeply to the north and south at angles of 15 or 20 degrees, and in some cases at steeper angles. (Plate IV, general section.) As stated on a preceding page, the colored cross-sections went to press in December, 1911, but underground work since then has rendered it necessary to make minor changes. These alterations have been made on uncolored second editions of plates I, II and V.

The following notes give details of the cross-sections, the locations of which are shown on the map, scale 800 feet to 1 inch.

Section A, B, C, plate I

Number 6 shaft of the O'Brien mine passed from the surface downward through the Nipissing diabase and encountered the Keewatin series at a depth of 225 feet. The levels and other workings connected with this shaft cut the floor of the diabase sill at several other points. The dip of the sill is therefore known fairly accurately. At the bottom of the shaft it is, according to the late Mr. M. T. Culbert, some 7 or 8 degrees to the east, but near the surface it becomes much steeper. The top of the sill has been preserved at the Colonial, Silver Cliff and King Edward by a capping of Keewatin greenstone. At the latter property, which is now leased by the York-Ontario, diamond drill operations during February and March, 1913, have shown that the diabase has an apparent thickness of about 1.150 feet. At about 666 feet below the top of the sill, however, what was described by Mr. H. E. Jackman as a "clay seam" one inch thick was met with, and thin sections from this point examined under the microscope showed the rock to be crushed and brecciated. Possibly the clay seam represents a fault which makes the sill appear to be thicker than it really is. From the map, scale 1 mile to 1 inch, it will be seen that the longer axis of Cross lake is on a line which traverses, to the southeast, Kirk, Chown and Goodwin lakes. This line of lakes indicates, in all probability, a fault or a fold, more likely the former. A reverse fault, with plane dipping to the southwest at a low angle, would account for the thickness of the diabase met with in the drill hole.

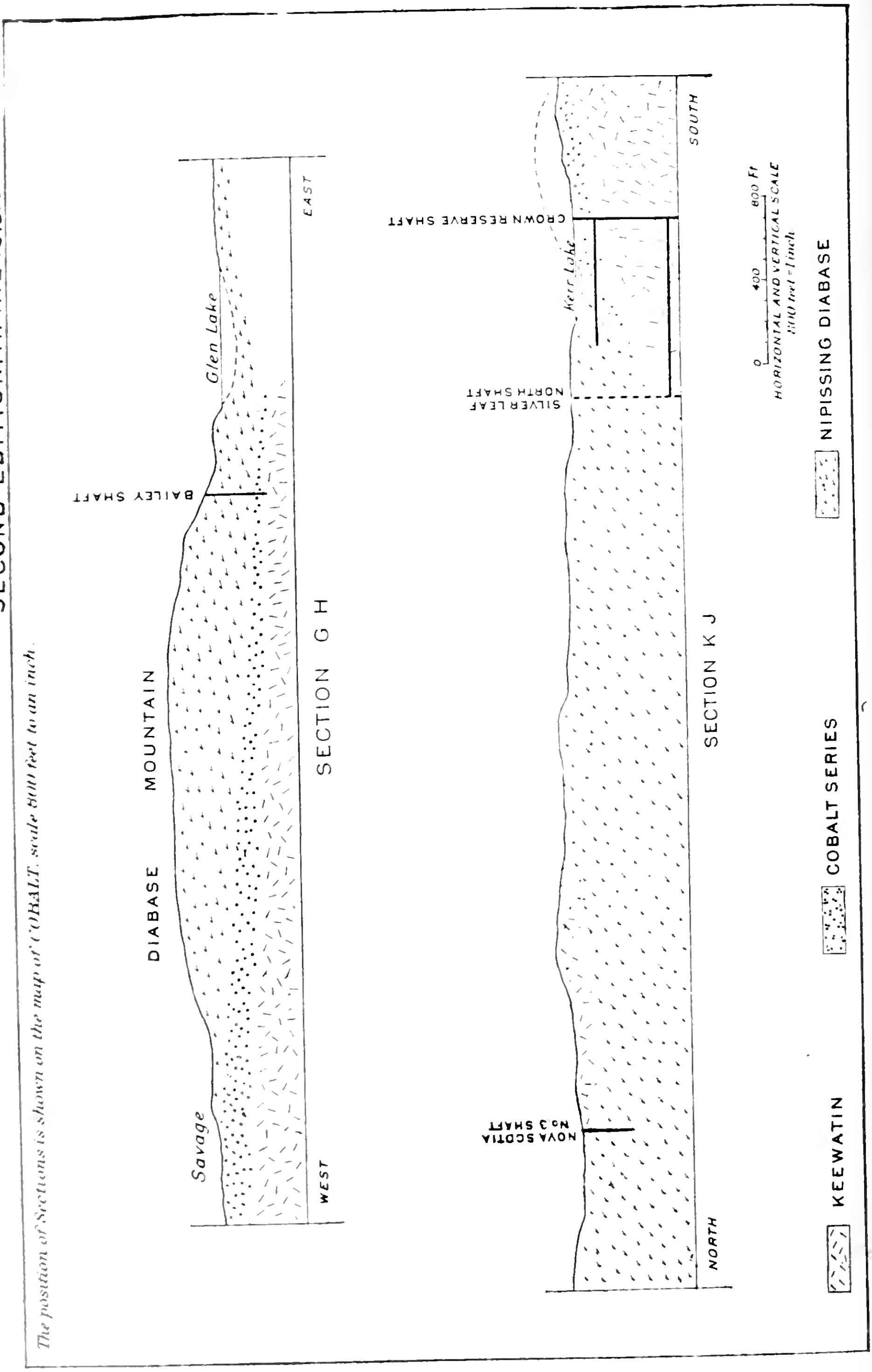
Section D, E, F, plate I

The first 10 feet of the Little Nipissing shaft is in the Nipissing diabase, below which the shaft is wholly in the Keewatin series. At the 160-foot level a drift runs easterly below Peterson lake a distance of about 500 feet, encountering Nipissing diabase the last 20 feet. The workings thus show that the sill dips to the east at an angle of about 16 degrees. In the cross-section the line indicating the floor of the diabase has been produced towards the Nova Scotia (where the top of the sill has been preserved), with gradually diminishing slope, in order to show the top and bottom of the sill in parallel position. In this manner the sill may be demonstrated to have a minimum thickness of 500 or 600 feet, but the actual thickness can of course only be determined by diamond drill or other means. The cross-section is about 400 feet south of the Little Nipissing shaft.

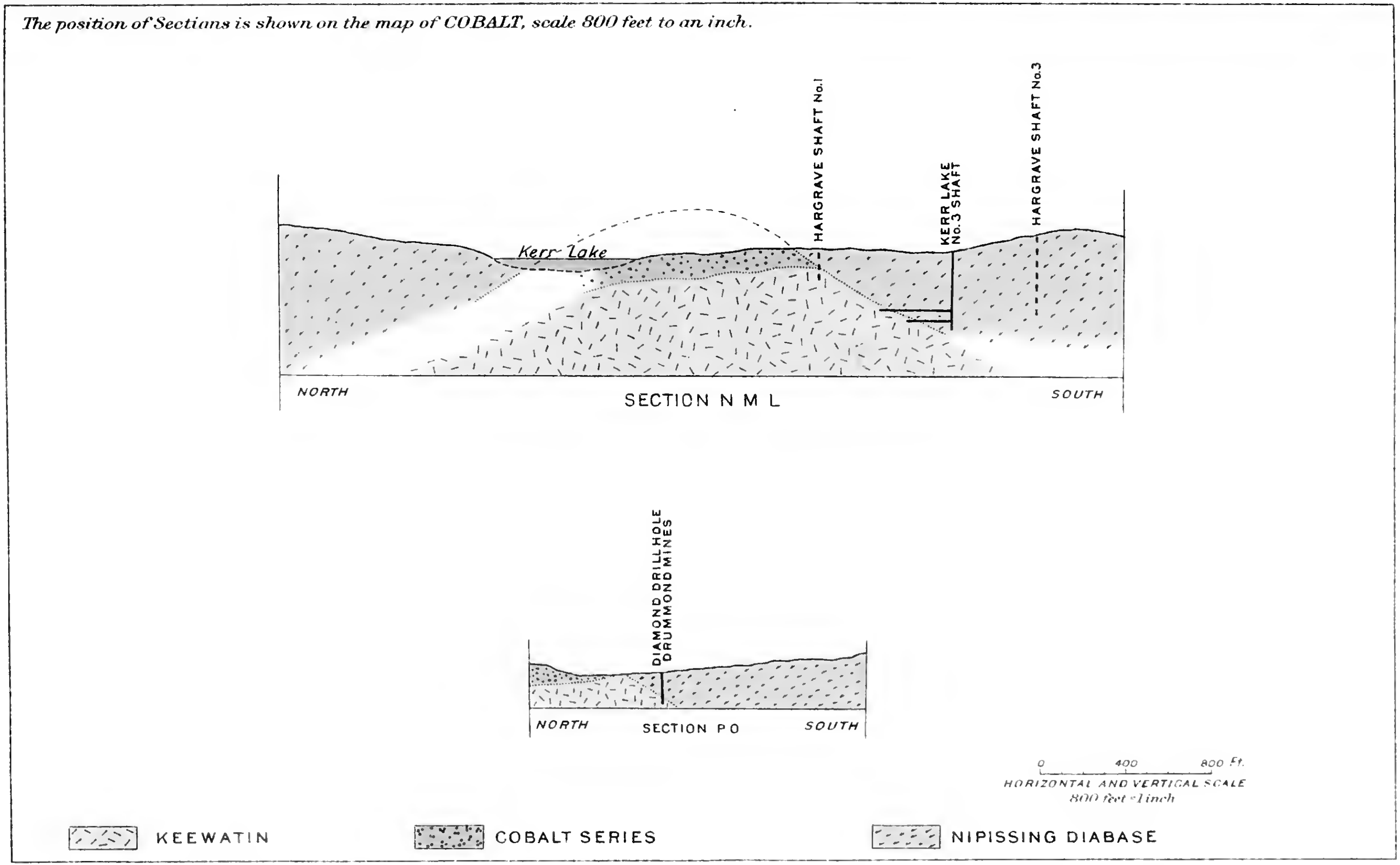
*Cobalt was originally in the judicial district of Nipissing. The diabase being widespread throughout this district, the name seemed a suitable one to give to it. On the earlier geological maps of the area we used the name post-Lower Huronian for the diabase, but it seemed best to adopt a simpler name. Recently the district of Nipissing has been subdivided. That part in which Cobalt is situated is now known as the Temiskaming judicial district. The district town is Haileybury.

PLATE II

SECOND EDITION, APRIL 1913.



The position of Sections is shown on the map of COBALT, scale 800 feet to an inch.



To accompany Fourth Edition of Report by **WILLET G. MILLER**, *Provincial Geologist, on the Cobalt-Nickel Arsenides and Silver Deposits of Temiskaming. In Part II. of the Nineteenth Report of the Bureau of Mines, Ontario.*

Section G, H, plate II

The Bailey shaft, on the eastern face of Mount Diabase, passes through 220 feet of diabase, after which 30 or 40 feet of flat-lying, slate-like greywacké of the Cobalt series are cut, followed by the Keewatin series. According to these figures the dip of the sill between the Savage and Bailey is 4½ degrees to the east. Probably the almost horizontal position of the sill in this area is due to the fact that the diabase has been intruded between the bedding planes of flat-lying greywacké slates. In other parts of the area where it has cut the complex Keewatin series or the conglomerates of the Cobalt series—which latter are for the most part devoid of regular bedding planes—it has irregular dips.

Section K, J, plate II

At the 100-foot level of the Crown Reserve shaft—which is in conglomerate, greywacké, etc., of the Cobalt series between this level and the surface—a drift runs northerly under Kerr lake. At a distance of 480 feet from the shaft the Nipissing diabase, resting on greywacké slates parallel to the bedding planes, is encountered, showing a dip of about 17 degrees to the north. On the same level in a nearby drift the dip is much steeper, being 45 or 50 degrees. The Silver Leaf north shaft on the north side of Kerr lake has been sunk 500 feet, and a crosscut run from the 480-foot level, southerly to the main shaft of the Crown Reserve. The former shaft, from the surface to about the 410-foot level, passes through Nipissing diabase, while the remaining lower part of the shaft and all of the crosscut pass through rocks consisting of lamprophyre, schist and diabase. The latter has, for the most part, an older, more decomposed appearance than the Nipissing diabase, and is made up of plagioclase and hornblende, together with epidote and zoisite. It may be, however, that there occur in this crosscut a few dikes from the Nipissing diabase.

The cross-cut shows no evidence of any great faults, but some minor slips are present.

Section N, M, L, plate III

No. 3 shaft, at the southeast corner of the Kerr lake mine, has been sunk in the Nipissing diabase. From the 274-foot and 322-foot levels drifts have been run to the north, passing through the diabase and cutting into the Keewatin series in both cases. At the No. 1 shaft of the Hargrave the diabase was passed through at the first level. It is thus seen that the dip of the diabase sill is 25 to 35 degrees to the south, the steeper angle obtaining towards the surface.

Section P, O, plate III

A vertical diamond drill hole on the south lot of the Drummond mine passes through 117 feet of diabase before entering the Keewatin series. The point of contact of the diabase on the surface is known, and the inclination of the diabase may thus be calculated to be about 35 degrees to the south.

General Section, upper half of plate IV

The section incorporates much of the information contained in the preceding sections, together with additional data. Its total length is about 4½ miles, and it may be added that the bottom line represents sea level. The cross-section begins at the southeast corner of Sasaginaga lake, and shows the important area of conglomerate, greywacké, etc., of the Cobalt series resting in an ancient valley of the Keewatin series between Cobalt and Sasaginaga lakes. A reverse fault—normal to the line of section—occurs parallel to the longer axis of Cobalt lake, and it is also found at the McKinley-Darragh and Princess at the south end of the lake, and at La Rose and Right of Way at the north end of the lake. (See plates V and VI.)

At La Rose mine the rocks on the west side of the fault have been carried down a vertical distance of 210 or 220 feet, and at the McKinley-Darragh a vertical distance of at least 250 feet.

The diabase at the Little Nipissing has already been shown to dip easterly at an angle of about 16 degrees, while at the Crown Reserve it has been proved to dip more steeply at angles varying from 17 to 45 or 50 degrees to the north, from which it appears that the sill occupies a basin-like depression in the underlying rocks between these two properties.

If the Kerr lake area be now studied it will be found that the diabase inclines more or less steeply to the north and to the south of the axis of the lake, forming a saddle-like structure. It may be seen dipping northerly at the following points: the southwest shore of Cross lake; the northeast corner of the north Drummond lot; about 200 yards east of Kerr lake and 25 yards north of the road; (a diamond drill hole near here has also proved the dip to be northerly); a trench on the Silver Leaf has exposed the contact of the diabase for about fifty yards or more. On the south flank of this saddle-like structure the diabase has been proved to dip southerly at the following points: the Valentine shaft; a vertical diamond drill hole on the south part of the south Drummond lot (see plate III, section P O; shaft No. 5 of the Drummond; shaft No. 1 of the Hargrave; two drifts from the No. 3 shaft of the Kerr lake (see plate III, section N M L); a drift from the 369-foot level of the No. 3 shaft of the Hargrave. From the above data it is thus seen that the saddle-like structure of the Nipissing diabase at Kerr lake has been proved at several points. But it may be added that some of the steep inclinations of the sill may be partly due to faulting. There is, for example, a well defined fault in the diabase at the Crown Reserve, 540 feet north of the shaft in the drift at the first level, dipping 15 or 20 degrees to the north. Again on the south side of the saddle-like structure a fault, dipping to the southeast, was encountered at the Hargraves and Drummond.

At the Lumsden a shaft was sunk in the Keewatin to a depth of 290 feet, where it passed into the Nipissing diabase, proving that the sill here dips beneath the Keewatin greenstones at an angle of 25 or 30 degrees. Similar relations are known to obtain at other points along the same contact to the southwest as far as Mount Greywacké.

Coming, finally, to the Temiskaming mine it is found that the Nipissing diabase has been encountered on the fourth and fifth levels, and at a depth of 575 feet in the main shaft. The surveys show that the sill dips at angles varying from 17 to 30 or 40 degrees in different parts of the mine, but it is probable that faulting may have caused some of the steeper inclinations, because a vertical fault between the diabase and Keewatin is known to occur on the fourth level. There are, however, no data at present to determine the throw of this fault.

Ideal Restoration, lower half of plate IV

An attempt is made in this plate to picture conditions during pre-Cambrian times, before erosion and faulting of the sill had taken place.

It will be noted that the position of the present land surface and the Cobalt lake fault are shown. It is obvious that, in restoring the part west of the fault to its position prior to displacement, the broken line showing the present land surface must, of course, be moved upwards a distance equal to the vertical throw. If this point is not considered when studying the cross-section one might, at first glance, get the erroneous impression that a normal fault had occurred, carrying down the east side of the lake, but the unbroken and continuous position of the diabase sill and floor of the Cobalt conglomerate will show that this is not the case.

Section Y, Z, plate V

The cross-section shows the great fault at La Rose mine as it has been worked out at and near the main shaft. It is a reverse fault, with a steep south-easterly dip at the surface which becomes less on the lower levels. There is a vertical displacement of 210 or 220 feet, but the extent of the horizontal movement has not been ascertained.

On the first level, 45 feet south of the main shaft, a drift runs west under the railway to the boundary of the property. The fault is encountered at a distance of

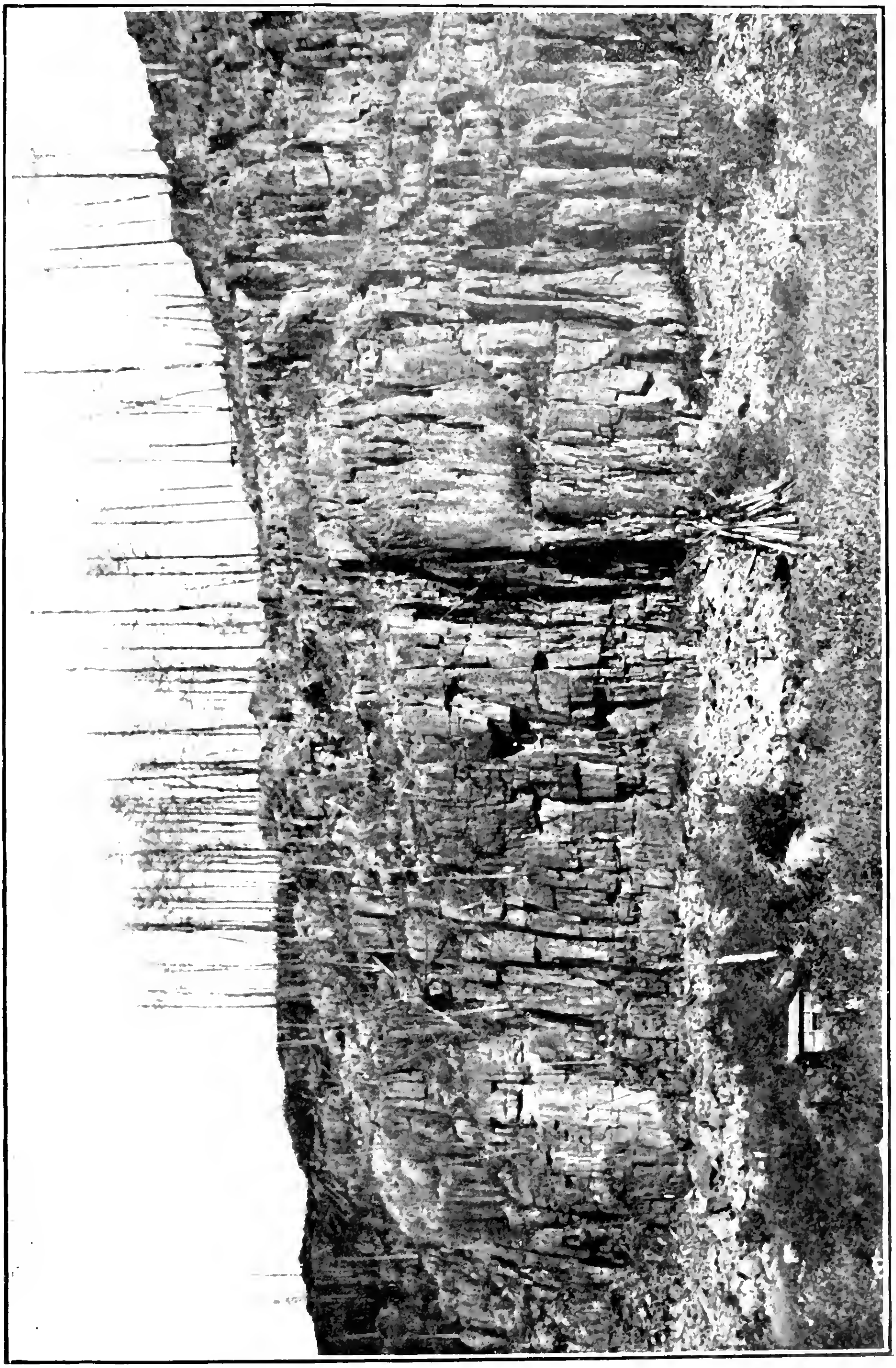


Fig. 43.—Nipissing Diabase, west face of Mount Diabase, Cobalt.

55 feet in this drift, and is well defined, because the Nipissing diabase sill has been carried down and a small uneroded patch now lies against the Cobalt series of sediments. The roof of the drift for 25 feet west of the fault, and the floor for 10 feet west, is diabase. On the surface the diabase outcrops west of the railway tracks, opposite La Rose main shaft.

On the second level the fault occurs 43 feet immediately west of the main shaft in a drift where coarse boulder conglomerate has been faulted down against fine-grained greywacké. The contact of the Cobalt series and the Keewatin greenstones occurs on this level at the main shaft.

On the third level the fault is found 12 feet east of the centre of the main shaft, and it may also be seen in the shaft itself at the top of the first ladder above this level. At these points the fault line is well shown, because the conglomerate and greywacké abut against the Keewatin greenstones.

In the winze at the third level the fault is met with several feet below the collar of the shaft.

At the 380-foot level the fault is again encountered in an easterly cross-cut 118 feet from the winze. Regarding operations at this point, R. B. Watson, the general manager, says in the sixth annual report of La Rose Consolidated Mines: " . . . The fault has been followed both ways for a total distance of over 500 feet. A strong vein of calcite, in places three feet wide, lies along the fault; it carries some silver throughout, but no high grade ore has been developed."

Finally, at the 500-foot level, a drift, which runs easterly, meets the fault 236 feet from the winze. A calcite vein, similar to that at the 380-foot level, also occurs in the fault here.

It is believed that the fault is younger than the veins because of the absence of any important amounts of silver or arsenides in the fault itself. A few ounces of silver per ton have been obtained from some samples in the fault. It is likely, however, that there have been recurrent movements, extending over a vast period, along or close to the line now occupied by the fault. Hence, it would be expected that veins might be found lying parallel to the fault, and some of them might have been reopened at the time the chief faulting took place.

Section W, X, plate VI

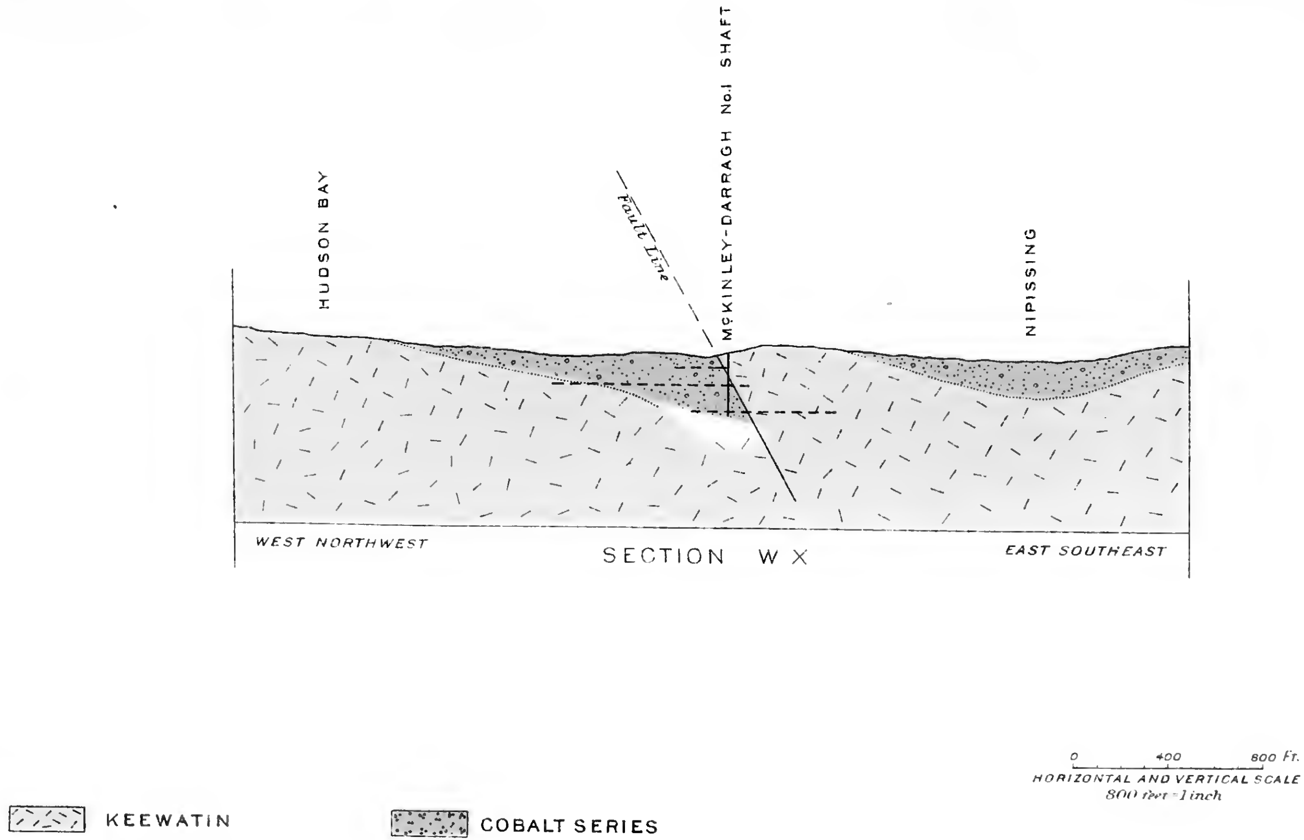
The fault at La Rose continues southwesterly through Cobalt lake, where it has been met with in the workings, and passes through the McKinley-Darragh and Princess. It is more striking at the McKinley-Darragh than at La Rose because in every case where it has been encountered on the three levels conglomerates, etc., of the Cobalt series abut sharply against the Keewatin greenstones. It dips southeasterly at an average inclination of about 60 degrees, and the throw has been proved to be at least 250 feet, but is believed to be greater. Mr. P. A. Robbins found ore in a brecciated condition in the fault, and considers the latter to be younger than the veins. As previously said, there may, however, have been recurrent movements along the line of weakness, extending throughout a vast interval of time. The rock on each side of the fault is much broken. Other minor displacements occur, some of them being later in age than the veins.

Openings Through which Diabase Ascended

In the Cobalt area proper the diabase, as will be seen from the accompanying cross-sections and descriptions, is in the form of a sheet or sill, which has intruded all the older rocks of the area. While there are local variations, the dip of the sill, on the whole, is at a low angle, 15 or 20 degrees, to the east or southeast. While it cannot be definitely proved, it appears that all the diabase of the sill at Cobalt came from a single opening. In the surrounding areas the diabase probably came from other openings.

On a preceding page it is suggested that the absence, in the veins of Cobalt, of barite and fluorite, characteristic minerals of similar cobalt-silver veins in other parts of the world, is to be accounted for by the fact that the diabase and mineral-bearing solutions in ascending followed for a considerable distance an almost horizontal direction, shown by the dip of the sill. Barite and fluorite, which are usually among the

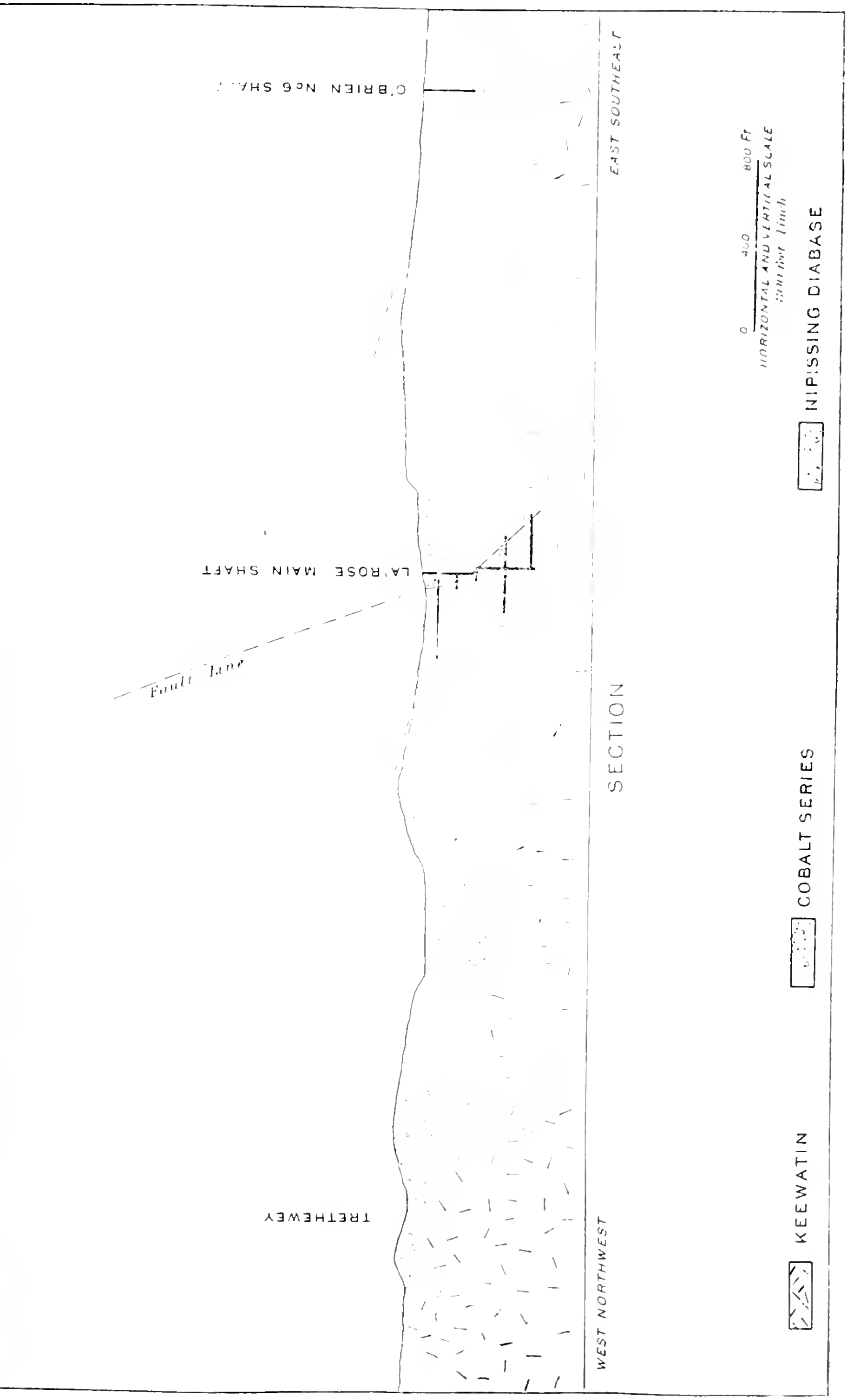
The position of Section is shown on the map of COBALT, scale 800 feet to an inch.



To accompany Fourth Edition of Report by WILLET G. MILLER, Provincial Geologist, on the Cobalt-Nickel Arsenides and Silver Deposits of Temiskaming
In Part II. of the Nineteenth Report of the Bureau of Mines, Ontario.

SECOND EDITION, APRIL 1913.

PLATE V



The position of Section is shown on the map of COBALT, scale 800 feet to an inch.

first of the minerals to be deposited in such veins, would probably be precipitated before the solutions reached the part of the area where the veins are now found.

One or two veins in the diabase near Elk lake, and a few small ones in the same rock in the Gowganda area, contain barite. This mineral and fluorite are found in veins carrying native silver in the township of Langmuir, near Porcupine. It would seem that these veins in the outlying areas owe the presence of the minerals to the fact that the diabase has risen in a more vertical direction than at Cobalt.

Sills Elsewhere

The hypabyssal rocks, such as diabase, basalt and andesite, are more frequently found as sills than are the deeper seated rocks: granite, syenite and others.

Many sills of diabase, or closely related rock, are known. For instance, on the north shore of Lake Superior, near Port Arthur, there are sills of great extent.

The palisades of the Hudson, New York, are formed by a sheet or sill, the outcrop of which is 70 miles long from north to south, and its thickness varies from 300 to 850 feet; the dike which supplied this immense mass is exposed in a few places along its western side.*

In the north of England the Great Whin sill, somewhat like that of Cobalt in chemical composition, is another famous example. It is traceable for a distance of 80 miles and has a total area of perhaps not less than 1,000 square miles. It varies in thickness from less than 20 to as much as 150 feet, but averages from 80 to 100 feet.†

It is thus seen that the size of the productive area at Cobalt is small when compared with the known horizontal extent of certain sills elsewhere.

2. MICROSCOPICAL AND CHEMICAL NOTES ON THE DIABASE

In the first and second editions of this report this diabase was spoken of as "diabase and gabbro" owing to the fact that some varieties are coarse in grain and thus resemble gabbro. Mr. Knight has found, however, that nearly all varieties of the rock from the Cobalt area, examined by him, possess an ophitic texture and should be called diabase. Primary quartz is almost always present in this diabase.

This rock, as will be seen from the maps, occupies a considerable part of the Cobalt area. Good contacts are found, especially between it and the Cobalt series. A contact of diabase with the Lorrain quartzite can be seen along the shore of Temiskaming a short distance north of Martineau bay, and elsewhere.

That the cobalt ores in all probability came from the same magma as the diabase is made evident from the association of these ores with the rock over a large territory.

Elsewhere in this report it has been stated that the Nipissing diabase is often much like some of the coarser varieties of basic rocks which are found in the Keewatin. Representatives of the latter, especially on freshly broken surfaces, have a more weathered and altered appearance than have Nipissing representatives.

Mr. Cyril W. Knight has furnished me with the following detailed descriptions of types of the diabase from various parts of the Cobalt area.

For a microscopic description of the diabases outside of the immediate vicinity of Cobalt, Dr. Barlow's report on the Temiskaming map sheet may be consulted,‡ and the papers by W. H. Collin§ and N. L. Bowen.

In many cases the microscope must be made use of in order to detect the ophitic texture, because it is not often that this texture can be made out with the naked eye. The grain of the rock is very uniform, the individuals of augite and plagioclase probably averaging between 1-16 and 1-8 of an inch in length. There are, however, places where it is very much coarser than this, as for example on the north shore of Peterson lake, near the creek.

The main point brought out in the following description is the fact that two-thirds of the thin sections examined contain primary quartz though seldom in considerable amount. They are therefore quartz-diabases. The quartz is almost always associated

*W. B. Scott, An Introduction to Geology, 1897, p. 280.
†Geikie, Text-Book of Geology, p. 733.
‡Annual Report Can. Geol. Sur., 1897.
§Economic Geology, Sept., 1910.
Jour. of Geol., Oct.-Nov., 1910.

with feldspar in what is known as a micrographic intergrowth, so that its primary nature may, therefore, be safely assumed.* This intergrowth is the last constituent to crystallize out and occurs between the interstices of the other minerals. In this connection it is interesting to note that some of the basic rocks (norite) at Sudbury also contain quartz, and both districts produce nickel and cobalt; the similarity of the two rocks is more fully discussed on pages 103-6. The quartz-diabases at Cobalt are evidently similar to those on the Blanche river, first rapids, described by W. G. Miller in the Bureau of Mines report for 1902, page 228.

(*a*) The diabase belt south of Kerr and Giroux lakes.

A thin section of the diabase near the southeast corner of the Kerr Lake property shows the rock to be a normal diabase and to consist of the following constituents: plagioclase, augite, biotite, magnetite and an odd grain of quartz.

The plagioclase occurs in long, relatively narrow rods, nearly always showing albite twinning lamellæ. The maximum extinction in sections at right angles to these lamellæ is 43 degrees, showing that the feldspar is labradorite (ab_3 an_7). Zonal banding is seen in a few cases with crossed nicols. The mineral is usually fresh but has sometimes altered to epidote, chlorite, etc. The augite occurs in pale brownish, faintly pleochroic, allotriomorphic grains. In almost every case there is present a very fine lamination which is due to parting parallel to OP (001).† This parting is sometimes present to the exclusion of the ordinary prismatic cleavage of the pyroxenes and occurs in almost all the augite in the diabase at Cobalt. It is sometimes combined with twinning on the orthopinacoid, giving the "herring-bone" structure. A few irregular grains of biotite are present. This latter mineral is always a constant, though never prominent, constituent of the rock. A very small amount of quartz (not in micrographic intergrowth with feldspar) and some magnetite are present.

The plagioclase has crystallized out before the augite, so that rods of the former are found partly or wholly embedded in the augite. This is known as the ophitic texture, and the rock is therefore classed as a diabase.

A specimen from the east end of Giroux lake (from the centre of what is known as the "Nugget" claim) contains the same constituents as those in the section just described. The quartz, however, is present in large enough quantities to class the rock with the quartz-diabases, but better examples of that type of rock will be described later. Decomposition has broken down much of the plagioclase to saussurite, and much of the augite to fibrous hornblende, chlorite, etc. The basal parting in the augite is very marked.

A specimen from Dynamite island in Giroux lake shows the rock to be a normal diabase without any quartz. It consists almost wholly of labradorite and augite, with a very few grains of biotite and magnetite. An occasional rod of apatite is seen. The texture is ophitic, the labradorite occurring in rods partly or wholly embedded in the augite. This section (and that from the Kerr Lake property) is fresher than most of the Nipissing diabase at Cobalt.

The rock from Diabase point, Giroux lake, is a good example of a quartz-diabase. The quartz is intergrown with feldspar, showing a micro-pegmatitic texture; the feldspar in this intergrowth is usually too badly decomposed to determine its nature. The rock consists of labradorite, augite, quartz and small amounts of biotite and ilmenite (partly decomposed to leucoxene). The labradorite is not quite so basic as in other diabases which are free from residual quartz. The ophitic texture is marked.

As will be seen from the geological map of Cobalt, the diabase belt south of Kerr and Giroux lakes is about three quarters of a mile wide. A specimen from the south edge of it (S.E. corner of lot 2, con. IV) shows the rock to be badly decomposed. It consists of plagioclase, augite, quartz, ilmenite and biotite. The plagioclase is almost wholly altered to saussurite, the augite to green hornblende, chlorite, etc., and the

*Harker, p. 132.
†Rosenbusch Iddings, Pl. xix, fig. 6.

ilmenite to leucoxene. The quartz is in graphic intergrowth with feldspar. It is therefore classed as a quartz-diabase, the plagioclase having crystallized out before the augite, giving the ophitic texture.

A thin section near the northwest corner of the University mine shows the rock to be a quartz-diabase. The quartz, however, is not such a prominent constituent as in sections from other parts of the area. The plagioclase occurs in the usual rods, showing albite twinning lamellæ and giving extinction angles (in the zone normal to the twinning lamellæ) up to 36 degrees. The augite occurs in allotriomorphic grains, showing twinning parallel to both 101 and 001, the latter repeated, resulting in the basal lamination already described in other augites. Biotite is present sparingly. A few grains of magnetite occur. The texture is ophitic.

(*b*) The diabase area between Kerr and Peterson lakes (on the south and north) and between Cross lake and the west face of Mount Diabase (on the east and west).

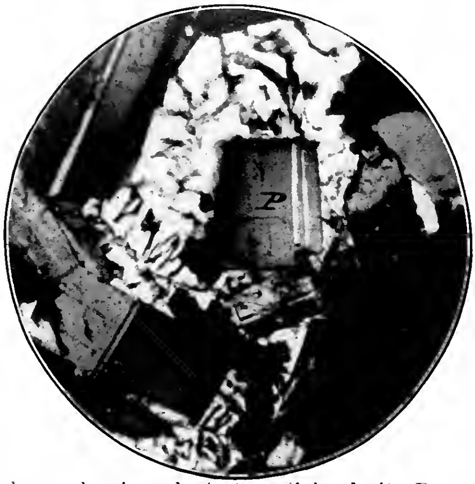


Fig. 44.—Quartz-diabase, showing plagioclase (labradorite P, embedded in a micrographic intergrowth of quartz and feldspar. From Diabase point, Giroux lake.

A specimen near the northeast corner of the Silver Leaf mine is a normal diabase similar to others already described. Northeasterly from this point about half a mile, a specimen was collected near lake Cyril. It consists of labradorite in the usual rods, augite showing the basal lamination so commonly found, biotite in accessory amount, magnetite, and quartz in graphic intergrowth with feldspar. The labradorite is badly decomposed, while some of the augite has been altered to uralite. There seems to be, however, some original hornblende present. The ophitic texture is well marked, placing the rock with the quartz-diabases.

(*c*) The diabase north of Peterson lake.

Good specimens may be obtained from the creek at the point where it leaves Peterson lake. The lake has been partly drained here by a small canal cut in the rock. The texture of the rock is unusually coarse, the augite individuals being sometimes half an inch in length. The labradorite occurs in shorter rods than is the case with most diabases, but it has crystallized before the ferro-magnesian mineral. The maximum extinction angle in the zone normal to the twinning lamellæ is 34 degrees. Much of it is decomposed to saussurite. The augite shows the characteristic basal lamination and some of it has decomposed to green pleochroic hornblende. Biotite in accessory amount is present. Quartz is found partly in graphic intergrowth with feldspar and partly by itself. In the latter case its primary origin may sometimes be in doubt. Some magnetite grains are noted. The typical ophitic texture is not well developed, but the plagioclase has crystallized before the pyroxene, and in a few cases the usual rods of the former are wholly embedded in the augite.

Northeasterly from here half a mile, on the Watts (King Edward), the thin section examined is less coarse in grain. The labradorite is in the usual rods, partly decomposed to saussurite. The augite occurs in allotriomorphic grains, showing the basal lamination, and it has in part been altered to uralite. The micrographic intergrowths of quartz and feldspar are more abundant than in any so far described. Ilmenite, mostly weathered to leucoxene, is also unusually abundant. The rock is a fine example of quartz-diabase.

Northerly from this point two-thirds of a mile (the northeast corner of the O'Brien) a thin section shows the rock to be a quartz-diabase. It is similar to others already described, consisting of labradorite, augite (showing basal lamination), quartz and feldspar in micrographic intergrowth, and small amounts of biotite and ilmenite (weathered to leucoxene). The texture is ophitic.

Five hundred feet due east from the point where the last specimen was taken the type of rock is a little different from the characteristic diabase at Cobalt. The plagioclase is an acidic labradorite (ab_1 an_1) partly in rods, partly in allotriomorphic grains.

Fig. 45.—Quartz-diabase. P, plagioclase (labradorite) embedded in a micrographic intergrowth of quartz and feldspar, Q. From northeast corner of R L 403, O'Brien mine.

There is no augite present, its place being taken by a faintly pleochroic hornblende, occurring partly in rods but mostly in allotriomorphic grains. Some magnetite is present. Part of the plagioclase has crystallized before the ferro-magnesian constituent, while some has crystallized about the same time; hence the ophitic texture is not marked.

A specimen of the diabase from No. 6 shaft of the O'Brien mine was collected and examined by the late Mr. M. T. Culbert, who found it to contain a pyroxene with parallel extinction and low interference colors, and who considered it to be enstatite. A similar mineral occurs in some of the diabases described above. Mr. N. L. Bowen* has also found enstatite in a thin section from the diabase at Gowganda, and says that "the slide presents no difference whatever from the diabase of the Cobalt area."

The diabase on the west part of La Rose property does not differ materially in composition or texture from the typical outcrops in other parts of Cobalt, except that it is finer in grain. Rods of labradorite set in allotriomorphic grains of augite essentially constitute the rock, and the usual decomposition products have resulted in places. Ilmenite and a small amount of quartz and feldspar in micrographic intergrowth are also present. This diabase outcrop on the west side of the railway, opposite La Rose mine, is on the downthrow side of a fault.

*Jour. Geo., Oct.-Nov., 1910.

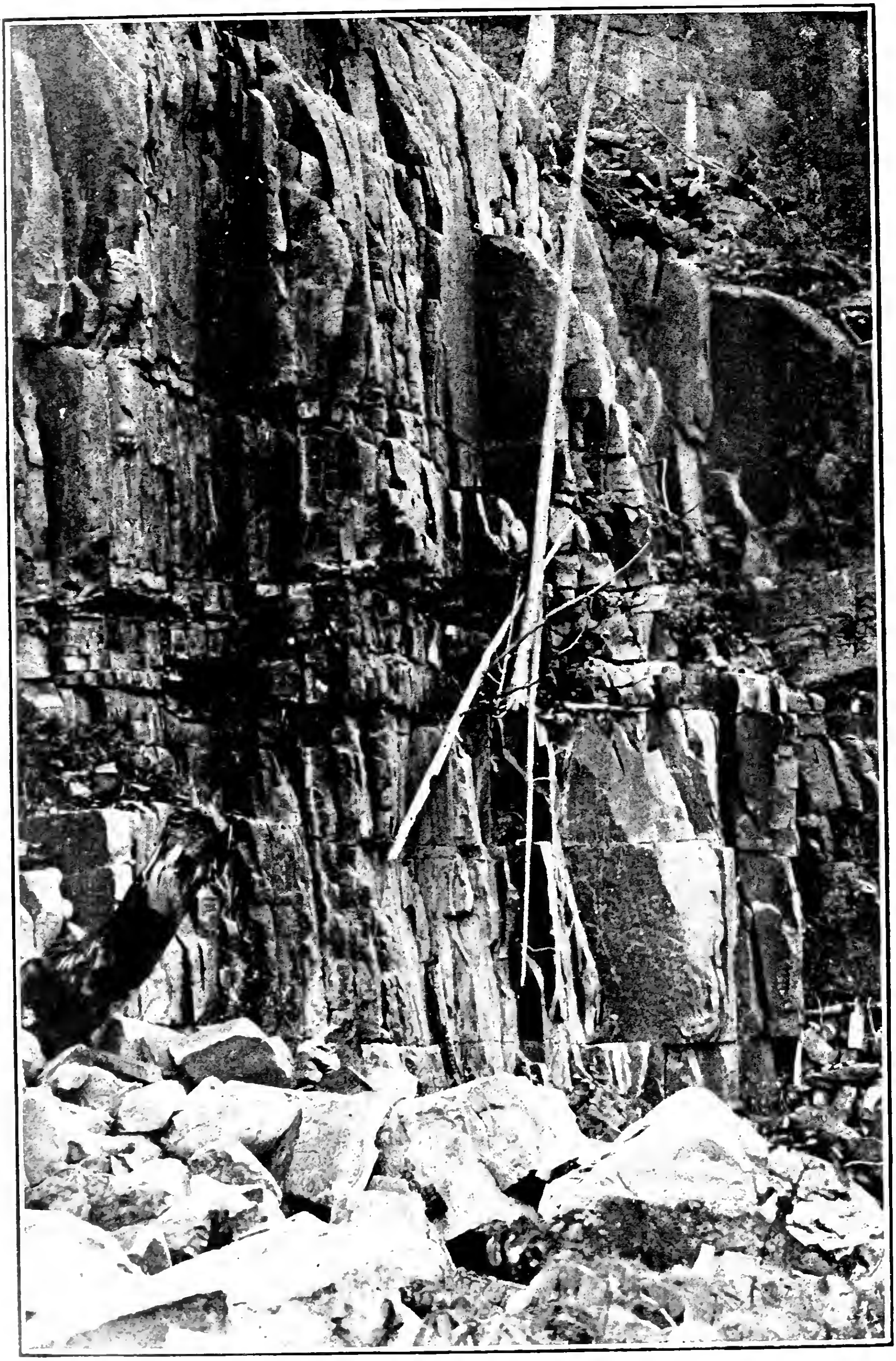


Fig. 16. Jointing planes in diabase on west face of Mount Diabase, Cobalt.

Three sections were examined which are a little outside the Cobalt silver area proper. They are all quartz-diabases. One of them, taken beside the Temiskaming and Northern Ontario Railway between Bass and Mud lakes, shows the rock to contain labradorite, hornblende, small amounts of augite, abundant quartz in micrographic intergrowth with feldspar, and ilmenite. The labradorite is nearly all decomposed to saussurite and the hornblende present seems to have resulted from the augite. The texture is ophitic. Another specimen, also beside the railway, was collected about half a mile farther west, between Mud lake and the Montreal river. It is similar to the last specimen, with the exception that it contains accessory biotite.

A specimen from the Imperial Cobalt, near Portage bay, south part of lot 15 in the sixth concession of Coleman is seen to be much decomposed, and is represented now largely by green pleochroic hornblende. Rods of plagioclase, nearly always altered to secondary products (saussurite), can be seen embedded in hornblende giving the ophitic texture. The section contains considerable quartz in graphic intergrowth with feldspar, the latter in some cases twinned. It is this feldspar which gives the rock, like most of the diabase in the Portage bay area, the appearance of containing pink or reddish grains. The rock may be called a quartz-diabase. It contains more quartz than any of the diabase in the immediate vicinity of Cobalt.

(*d*) Note on chemical composition.

Mr. A. G. Burrows made silica determinations of two of the quartz-diabases. The SiO_2 content of the rock between Mud lake and the Montreal river is 51.14 per cent. The other determination was made from the quartz-diabase from Diabase point, Giroux lake. It contained 49.44 per cent. SiO_2. Rosenbusch gives analyses of two quartz-diabases showing a SiO_2 content of 51.15 and 55.25 per cent. Analyses are given on a following page.

Facies of the Diabase

While, as will be seen from the thin sections that have been described, the diabase in the productive part of the Cobalt area is fairly uniform in character, differentiation is found in the outlying areas. Thus, a few miles to the west and also to the south of Cobalt pink spots, areas of micropegmatite, appear in the diabase. In certain localities these pink spots increase until the rock becomes pink or reddish, and is then more correctly described as granophyre than as diabase. A similar, but more complete change from a basic, darker rock to a lighter colored, more acidic variety, is found in the norite of Sudbury.

At times the typical diabase passes into a rock much coarser in grain, that has been described as gabbro, but many of these coarser varieties, when examined closely, are found to have the ophitic texture.

DIKES OF APLITE OR GRANOPHYRE YOUNGER THAN NIPISSING DIABASE

Especially in the Elk Lake and Gowganda areas the Nipissing diabase is frequently cut by narrow dikes of aplite or granophyre. The material in these dikes is believed to represent residual, acidic segregations of the diabase magma. On the cooling of the diabase cracks were formed in it, and material from the residual magma rising through the cracks and fissures formed the dikes of aplite or granophyre. Chemical and microscopical examinations of these dike rocks show that they are genetically connected with the diabase rather than with granite. Compared with the fine-grained granite or felsite dikes in the region, such as those connected with the Lorrain granite, the aplite dikes associated with the Nipissing diabase are found to be characteristically high in soda and low in potash, as following analyses show.

At Cobalt there is a dike of granite on the property of the University mine that cuts the Nipissing diabase, and from its chemical composition is seen to be related to the aplites of Gowganda and Elk Lake. Having a much greater width than have the characteristic dikes elsewhere in the region, it is naturally coarser in grain. An analysis of samples from this dike is given below.

Examined in thin sections under the microscope the University mine dike rock is found to be made up of feldspar, quartz and a colored constituent. The feldspar predominates, and consists of microcline and an acid plagioclase showing fine albite twinning lamellæ. The quartz and feldspar occur in allotriomorphic grains, but in two instances show distinct micrographic intergrowths. The colored constituent is not abundant; it was apparently originally a mica, but is now represented by chloritic material.

This dike averages fifty feet in width, while the dikes of the Montreal river area and Gowganda are usually under eighteen inches.

Analyses

The table below gives analyses of the acid or granophyric facies of the eruptives at Cobalt and Sudbury, and brings out the chemical relations of the rocks of the two areas.

——	I.	II.	III.	IV.
SiO_2	72.33	62.54	61.93	67.76
Al_2O_3	12.99	14.79	13.03	14.00
Fe_2O_3	none	....	.56	....
FeO	2.50	8.49	8.00	5.18
MgO	.97	2.08	1.76	1.00
CaO	1.73	1.49	4.02	4.28
Na_2O	7.60	6.27	3.18	5.22
K_2O	none	1.12	2.80	1.19
H_2O	1.09	3.51	1.95	1.01
TiO_2	.74	....	.84	.46
P_2O_5	....	....	.32	.19
MnO	....	....	.18	trace
CO_2	1.00	....	....	....
S	....	....	.19	....
	100.95	100.29	98.76	100.29

I. University mine dike, N. L. Bowen, analyst (Jr. Can. Min. Inst., Vol. XII.).
II. Lost Lake granophyre, Gowganda, N. L. Bowen, analyst.
III. Acid edge of nickel eruptive, Onaping section, Sudbury. E. G. R. Ardagh, analyst.
IV. Near acid edge of the Blezard-Whitson lake section, T. L. Walker, analyst.

The granophyre at Sudbury is the acid phase of the norite. On a following page are given analyses of the Sudbury norite and Nipissing diabase of Cobalt. These important ore-bearing rocks of the two areas are apparently of the same age, and are believed to be genetically connected.

BASIC DIKES YOUNGER THAN NIPISSING DIABASE

In the region one hundred miles in width, between Sudbury on the southwest and Quinze lake, which lies to the east of the head of Lake Temiskaming, on the northeast, basic dikes have been found at many points. These dikes are younger than the Sudbury norite and the Nipissing diabase, which, of the basic igneous rocks, immediately precede them in age.

The age relation of these dikes to those of aplite or granophyre, described on a preceding page, which are believed to represent acidic, residual material of the Nipissing diabase magma, is not known. The basic dikes in all probability also came from this magma. In the Sudbury area these dikes are cut by greyish, fine-grained granite, the youngest intrusive of that area.*

At Sudbury the basic dikes are composed of olivine diabase which on weathering shows the characteristic spheroidal forms. In thin sections under the microscope the rock is one of the most beautiful of its class. On the Quinze river, a hundred miles to the northeast of Sudbury, similar dikes of olivine diabase have been described by the writer.†

In the region between Sudbury and the Quinze many dikes of olivine diabase have been found as well as those of olivine-free diabase.

In the vicinity of Cobalt these dikes are rare, the only one studied by the writer being the basalt-diabase of Cross lake, described in following paragraphs.

The post-Nipissing diabase, basic dikes of the Elk Lake, Gowganda, Temagami and other areas, have been described by Messrs. Barlow, Burrows, Collins, and other investigators, references to whose writings are to be found in this report.

Later Basalt-Diabase of Cross Lake, Cobalt

About the middle of the southwest shore of Cross lake, the Nipissing diabase is cut by a dark colored dike. At the immediate contact the dike rock is very fine in grain and is a basalt. Farther away from the contact it passes into a diabase. The basaltic facies is made up of plagioclase, olivine and magnetite or ilmenite. The texture is porphyritic. The plagioclase phenocrysts occur in narrow rods showing carlsbad, albite and sometimes pericline twins. Zonal banding is seen. Few of the crystals happen to be cut exactly normal to the albite twinning lamellæ, so that the composition cannot be definitely determined, but the feldspar is probably labradorite. The plagioclase in the ground-mass occurs in smaller rods of the same composition (labradorite). A tendency to flow structure is noted in these small rods. Olivine occurs both as phenocrysts and in the ground-mass. It is found in grains showing common crystal faces and also in rounded individuals. There is considerable opaque material lying in the interstices of the plagioclase rods. It is probably magnetite (or ilmente); some of it shows dendritic forms.

The diabase facies contains labradorite, augite, biotite and magnetite (or ilmenite). The labradorite occurs in the usual rods embedded partly or wholly in augite. The latter is in allotriomorphic grains with a faint violet brown color indicating the presence of titanium. Some biotite is present and also much magnetite (or ilmenite).

This later basalt-diabase as exposed on Cross lake is finer in grain than the earlier Nipissing diabase of the Cobalt area. Owing to drift covering its areal distribution has not been determined.

The following table shows the chemical composition of the dike rock at Cross lake. For comparison the composition of the olivine diabase and norite of Sudbury, and the Nipissing diabase of Cobalt, is given.

*14th Report, Ontario Bureau of Mines, Part III., pp. 14, 126.
†11th Report, Ontario Bureau of Mines, pp. 227, 229.

Analyses

—	No. 1.	No. 2.	No. 3.	No. 4.	No. 5.
SiO_2	45.20	47.22	49.84	48.06	49.90
TiO_2	....	3.62	....	....	1.47
Al_2O_3	19.08	16.52	18.94	18.23	16.32
Fe_2O_3	3.64	3.32	1.51 }	9.57	....
FeO	14.64	12.40	6.40 }		13.54
CaO	7.89	9.61	10.32	11.55	6.58
MgO	4.98	3.33	7.39	7.80	6.22
BaO	....	.01	....	....	....
Na_2O	3.32	3.40	1.99	1.87	1.82
K_2O	1.08	.67	1.28	.27	2.25
MnO	....	.04	....	....	trace
CuO	....	trace	....	....	....
NiO	....	.0275	....	....	....
CoO	....	.0055	....	....	....
P_2O_5	....	.33	....	....	.17
H_2O	....	.30	....	....	.76
Loss on ignition	....	....	2.57	3.54	....
Total	99.83	100.803	100.24	100.89	99.03
Sp. Gravity	....	3.01	....	....	....

No. 1, Basalt-diabase dike, Cross lake, Cobalt. No. 2, Olivine diabase dike, Sudbury. No. 3, Nipissing diabase cut by basalt-diabase dike at Cross lake. No. 4, Nipissing diabase, on the Violet property near Cross lake. No. 5, Norite, more basic than the average, at Sudbury.*

*Analyses Nos. 2 and 5 are taken from Dr. A. P. Coleman's paper in the Fourteenth Report, Ontario Bureau of Mines, Part III.

Fig. 46a.—Good roads at Cobalt.

PALEOZOIC

Silurian Limestone

It will be seen from the map (scale 1 mile to the inch), that the Niagara and Clinton limestone forms some large outcrops on the islands and in the vicinity of the shore near the northwest corner of lake Temiskaming. This limestone affords stone suitable for building and for the production of lime, and on this account should be of considerable value in the years to come, since the rock is a somewhat rare material in most of this northern part of Ontario. The district to the west and north is being rapidly settled and will soon contain a large population which will need much material for building purposes. The following is an analysis of a sample of limestone taken from Farr's quarry, Haileybury:

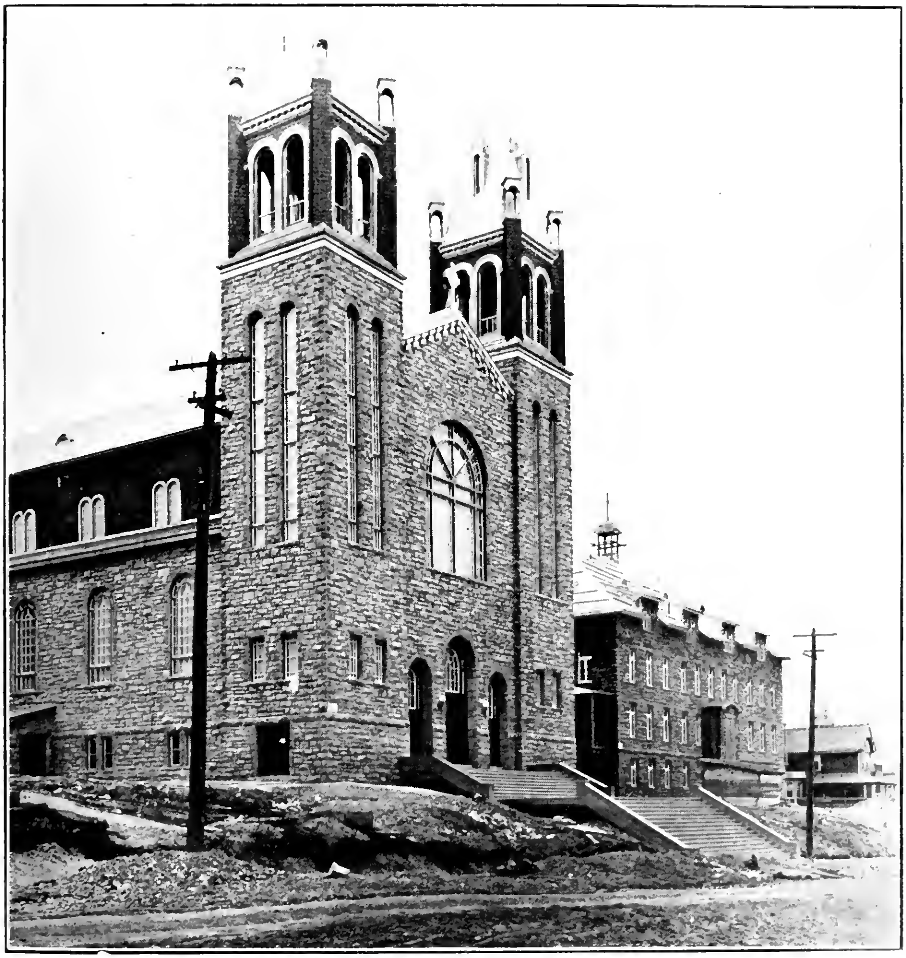


Fig. 47.—Holy Cross Cathedral, Haileybury, built of Niagara limestone, quarried near the town.

	Per cent.
Insoluble residue	1.60
Ferric oxide and alumina	.66
Lime	29.50
Magnesia	21.59
Carbon dioxide	46.84
Sulphur trioxide	.70
	100.89

This limestone formation extends northward, although overlain by clay and similar deposits in many places, and has been observed by the writer along the south branch of the Blanche river below what is known as the Mountain portage.

Considerable attention has been paid to the limestone area, Sir William Logan having first described it years ago. It has been shown that the series here is more closely related to the Niagara of Southern Ontario than it is to the Niagara areas to the north and west.

The cobalt-silver deposits being of pre-Cambrian age, the Paleozoic limestone is of little interest in connection with the ores. It is of course possible that ore-bearing rocks underlie the limestone.

Fig. 48.—Contact of quartzite of the Cobalt series with Niagara limestone, on the east shore of Lake Temiskaming, north of Piché point. The fragments of quartzite are cemented together by limestone.

Along the wagon road, in lots 5 and 6 in the third concession of the township of Dymond, to the northwest of the town of New Liskeard, the limestone cliff presents a striking face, indicating faulting. The fault line is continuous with the western shore of lake Temiskaming, and furnishes still further evidence confirmatory of the theory that the lake lies along a great northwest-southeast fault.

Additional notes on the Silurian, taken from Dr. A. E. Barlow's valuable report, are given in appendix I, on a following page.*

*Geo. Sur. Can., Vol. X., 1897, p. 123 I. See also Geology of Canada, 1863, p. 134.

PLEISTOCENE

Glacial and Recent

Immediately preceding the Glacial period, doubtless the surface of what is now the productive cobalt-silver area was in a highly weathered or decomposed condition. The glaciers scraped off this loose material from the surface and carried it southward, intermingled with other material. In all probability much more ore was carried away by the ice sheet than has been mined. Nuggets or boulders of rich silver ore have been found in prospecting trenches at numerous points to the south of the mines. A glacial boulder, worth about five thousand dollars, now in the Bureau of Mines collection, is described on a preceding page.

Everywhere throughout the region the surfaces of the rocks give evidence of glacial action. The underlying loose deposits, on the surface of the glaciated rocks, consist typically of boulder clay. This is succeeded upward, north of Cobalt, by a considerable thickness of strikingly well laminated clay (Fig. 49). Above this clay,

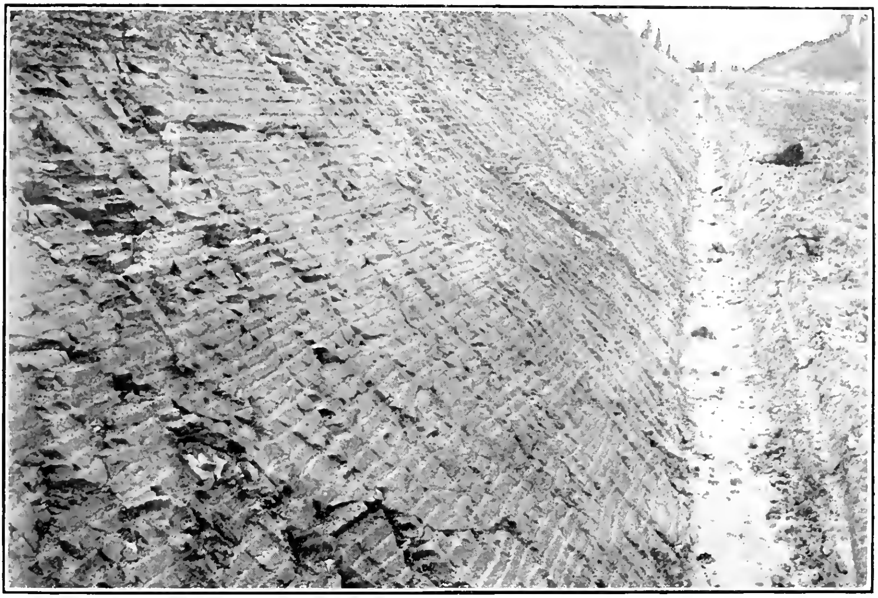


Fig. 49.—Bedded clay in railway cut between Haileybury and New Liskeard.

on some of the hills, to the north of lake Temiskaming, are sand and gravel deposits. The glacial deposits in this part of Ontario have been well described by Dr. A. P. Coleman.*

A couple of miles northward of Cobalt station the agricultural region of this part of northern Ontario is met with. The soil is essentially a well banded clay (Figs. 49, 50). Between this point and the height of land, or watershed, between the Hudson bay and Ottawa river waters, the clay does not form a continuous mantle, but there are large areas of tillable land which are being rapidly settled. Outcrops of solid rock, in many cases representing hill tops, which project through the clays, are seen. North of the height of land, however, is a large agricultural area, estimated at 16,000,000 acres, now traversed by the National Transcontinental Railway, and known as the "great clay belt," in which exposures of solid rock are few in number. The clay on both sides of the height of land is pretty uniform in character.

Following is an analysis of the clay in a cut on the railway between Haileybury and New Liskeard. It will be seen that the lime and magnesia are rather high. This

*Lake Ojibway; Last of the Great Glacial Lakes. Eighteenth Report, Ontario Bureau of Mines, p. 284 *et seq.*

is owing to alternate bands containing considerable marl. The clay effervesces strongly in acid.

	Per cent.
Silica	52.00
Alumina	16.11
Ferric oxide	4.69
Lime	8.26
Magnesia	4.10
Potash	1.74
Soda	2.76
Sulphur trioxide	.09
Loss on ignition	9.64
Total	99.39

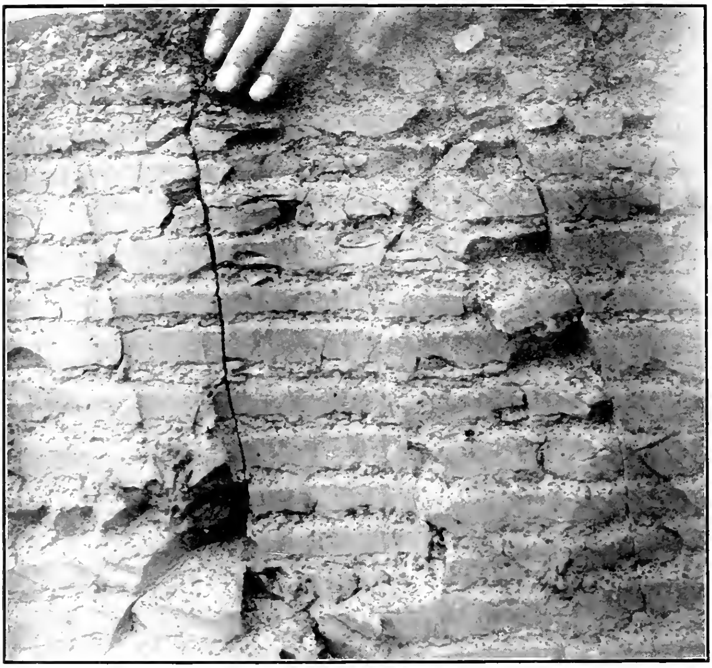


Fig. 50.—A part of the face of the cut shown in Fig. 49 enlarged.

Direction of Glacial Striae

The clay used in the manufacture of brick in the vicinity of New Liskeard is described by Mr. M. B. Baker in the 15th Report of the Bureau of Mines, Clay and the Clay Industry of Ontario, pages 83 and 84.

Concerning the glacial striæ on the rocks in the vicinity of lake Temiskaming Dr. A. E. Barlow says:*

"In the subjoined list, which is necessarily brief and incomplete, consisting of observations made during an exploration whose primary object was to map out and report upon the various subdivisions of the Archæan rocks, an attempt has been made wherever possible to tabulate in regard to their age the various striæ observed. Where two, three, or even four sets are noted as occurring on the same rock-surface, the order in which they appear is believed to represent, with approximate accuracy, their relative ages from the oldest to the most recent.

*Annual Report, Geol. Sur. Can., Vol X., 1897, p. 135 I.

List of Glacial Striae

"Wabis bay, west shore of, on lot 10, con. V, Bucke township	S. 15° E. S. 45 W.
Wabis bay, east shore of, on lot 2, con. I, Harris township	S. 19° E.
Sutton bay, northeast shore of, on lot 8 con. V, Harris township	S. 51 E.
East shore, west of Abbika creek, on lot 38, con. I, Guigues township	S. 81° E.
Chiefs island, east shore of	S. 36 E. S. 66 E.
Chiefs island, north shore of	S. 66° E.
Chiefs island, west shore of	S. 14° E. S. 48° E. S. 54 E.
East shore, on lot 31, con. I, Guigues township	S. 32 E.
Piché point, south of, on lot 12, con. I, Guigues township	S. 33 E. S. 46° E.
East shore, north of Wright's mine, on lot 7, con. II, Guigues township	S. 23° E. S. 43° E.
Wright's mine (Lake Temiskaming silver mine), on lot 62, con. I, Duhamel township, "Block A"	S. 21° E. S. 31° E. S. 60 E.
Joanne bay, east shore of, on lot 58, con. I, Duhamel township	S. 28° E. S. 14 W.
East shore, on lot 54, con. I, Duhamel township	S. 26° E. South
East shore, at Narrows with Bryson island, on lot 44, con. 1, Duhamel Tp.	S. 21° E.
East shore, opposite Drunken island, on lot 31, con. I, Duhamel Tp.	S. 4° W.
West shore, on lot 14, con. IV, Lorrain township	S. 4° W.
West shore, on lot 12, con. VI, Lorrain township	S. 21° E.
West shore, on lot 11, con. VII, Lorrain township	S. 12° W. S. 18° W.
West shore, on lot 15, con. I, Bucke township	S. 18° E. S. 26° W.
Laperriere bay, north shore of, ½ a mile east of old H. B. Co.'s post, lot 7, con. II, Duhamel township	S. 21° E. S. 6° W.
Islet near east shore, about 1 mile southeast of Roche McLean	S. 17° W. S. 32° W.
Roche McLean, near west shore	S. 10° E.
West shore, opposite Roche McLean	S. 4° E.
West shore, 1½ miles north of Montreal river	S. 4° W.
West shore, 1½ miles south of Montreal river	S. 21° E. S. 19° W."

The determination of the direction in which the ice sheet moved is of economic interest, since veins may be found by tracing to the northward the source of certain boulders. Such a method of prospecting was employed with success some years ago by the writer in the corundum area of southeastern Ontario.*

*Seventh Report, Ontario Bureau of Mines, p. 222.

DENUDATION AND DEPOSITION

Erosion in the District

While the following notes repeat some of the statements on other pages, it is thought well to deal with these subjects by themselves, since denudation and deposition, especially the former, have such important economic bearings in connection with the ore deposits of the region.

The rocks furnish evidence that proves there have been several changes of level in the district. During vast periods the surface stood above the level of the sea, and extensive erosion took place. During others, it was covered by the waters, and the deposition of sediment continued throughout great intervals of time.

The oldest rocks of the region are the Keewatin, described on preceding pages. In so far as can be determined, these rocks represent for the most part, submarine lava flows. It does not seem likely that in Keewatin times, there was no land surface on the globe, but, in so far as this region is concerned, little evidence has been found of the existence of such a surface. There may have been islands of comparatively small extent.

A great period appears to have elapsed after the extrusion of the Keewatin lavas under the waters of the primeval sea before the surface was elevated and extensive erosion began. During this period a thick series of sediments, the greater part of which may represent chemical precipitates, was laid down. None of these sediments are coarse in grain. Normally at the base, are found greywacké, whose component particles can, for the most part, be recognized only under the microscope. Above this comes impure slate or clay rock, often graphitic or containing considerable iron pyrites. In many parts of the region, iron formation or jaspilyte, interbanded silica and iron oxides, rests on the Keewatin, with a thin layer of greywacké frequently lying between the two, *e.g.*, near Temagami. Other sediments are represented by comparatively small outcrops of crystalline limestone. While the normal order of sedimentation appears to be greywacké, impure slate, iron formation and crystalline limestone, one or more of these may be absent when others are present.

The origin of the greywacké and impure slate cannot be definitely determined. Whether they represent land-derived sediments, or whether they come from volcanic fragmental material, connected with the submarine lava flows and more or less decomposed by sea water, is not known. That clays and coarser sediments are formed by the decomposition of rocks in sea water is well known.

"Passing over at present the organic deposits which form so characteristic a feature on the floor of the deeper and more open parts of the ocean, we come to certain red and grey clays found at depths of more than 2,000 fathoms, down to the bottom of the deepest abysses. These, by far the most widespread of oceanic deposits, consist of exceedingly fine clay, colored sometimes red by oxide of iron, sometimes of a chocolate tint from manganese oxide, with grains of augite, feldspar, and other volcanic minerals, pieces of palagonite and pumice, nodules of peroxide of manganese and other mineral substances. . . . These clays result from the decomposition of pumice and fine volcanic dust transported from volcanic islands into mid-ocean, or from the accumulation of the detritus of submarine eruptions."*

"The study of the dredgings has inclined the students of these materials to the conclusion that volcanic materials, rather than shells, are the principal source of the red clay."†

Little is known of the character of the products formed by the decomposition, under water, of the surface of submarine lavas. But it seems not unlikely that a relatively thin layer of impure clay or greywacké, resembling somewhat that found in certain localities on the surface of the Keewatin, may be thus formed. Knowledge of

*Geikie, Text-Book of Geology, Fourth Edition, p. 583.
†Chamberlin and Salisbury, Geology, Vol. 1., p. 366

deep sea deposits is limited to thin superficial layers. Soundings do not usually penetrate more than a few inches, or at most a foot or two, and the character of the weathered surface of the underlying rock is not known.

These sediments, that now occur in isolated areas on the surface of the Keewatin throughout northern Ontario, are in some respects unique when compared with those deposited in Paleozoic and later times. Jaspilyte has been found on most of the continents in association with the oldest rocks, but has no parallel among those of later age. In all probability these ancient sediments had a much greater thickness than is now apparent and formed a practically continuous covering on the Keewatin. Erosion has removed the greater part of them; the outcrops left represent remnants that have been preserved in depressions in the Keewatin, formed by folding, or through faulting or other means.

The group of sediments is similar to that of southeastern Ontario, to which the name Grenville is applied, and which has been estimated to have a thickness of thousands of feet.

It is not unlikely that these rocks in northern Ontario had a similar thickness, but they have been subjected to more intense erosion than have those of the southeastern part of the Province.

Intruding both the Keewatin and the overlying Grenville sediments are the Laurentian granite and gneiss. The intrusion of the Laurentian was probably connected with mountain building, the Keewatin and Grenville rocks being raised above the waters.

The First Great Period of Erosion

After the intrusion of the Laurentian, the rocks were subjected to a great period of erosion, and the conglomerate, greywacké, quartzite and other sediments, known as the Temiskaming series, were deposited as the land surface was gradually depressed.

It is impossible to say what was the thickness of the Temiskaming series. It has been deeply eroded, and only remnants of it are found throughout the region surrounding Cobalt. Mr. J. G. McMillan, from a study of exposures of the rocks in Midlothian township, north of Gowganda, is of opinion that in that area the thickness is approximately 7,000 feet.

Lorrain Granite Intrusion and Second Period of Erosion

The Temiskaming series is penetrated by at least one group of eruptives, *e.g.*, lamprophyre dikes, older than the Lorrain granite. Probably contemporaneously with the intrusion of the latter rock, the region was subjected to great disturbance and the Temiskaming series and older rocks were intensely folded, or in other words there was a second period of mountain building.

After this began another great period of erosion, during which vast quantities of material were removed from the surface. The products of this erosion are now represented by conglomerate, greywacké, and other rocks of the Cobalt series. At the end of this erosion the folded Temiskaming series was completely worn off the surface over a great part of the region, and only isolated outcrops of it were left. The Cobalt sediments rest in one place on the Keewatin, and at another on the Lorrain granite or on the Temiskaming series, illustrating the deep erosion that gave rise to them.

Nipissing Diabase Intrusion and Third Period of Erosion

After the Cobalt sediments had become compact and hardened, the intrusion of the Nipissing diabase took place. Succeeding this intrusion the region was again subjected to prolonged erosion before subsiding beneath the waters. If, as suggested elsewhere in this report, the Nipissing diabase is of Keweenawan age, a fairly close estimate can be made of the length of this period of erosion, since Silurian rocks, Clinton and Niagara, were the next to be deposited.

The Ordovician period, and probably part of the end of the pre-Cambrian, is unrepresented by rocks in the region. During this period thick deposits of sediments

were being formed in the southern part of the Province, along what are now the shores of lakes Ontario and Erie, and to the north on what is now the James Bay slope. Sediments representing series of rocks that are absent in the region surrounding Cobalt may have been deposited and afterwards removed by erosion.

Erosion Since the Niagara Period (Fourth Period of Erosion)

During the almost inconceivable time that has elapsed since the deposition of the Niagara rocks, the region has been subjected to intense erosion.

From the fact that Paleozoic rocks younger than the Niagara are found in both the more northern and southern parts of the Province, it is possible that such rocks were deposited in the region under review. If this was the case, the material has been completely removed by erosion, no trace of its presence remaining.

Depth of Erosion

The depth to which erosion reached in each of the four periods of denudation, to which reference has been made, and the quantity of material removed from the surface cannot be determined. That in each of these periods a great thickness of rock was worn off the surface is evident not only from the deposits resulting from the erosion, the Temiskaming and Cobalt series, but also from observations that have been made in certain parts of eastern North America and elsewhere, in localities where the depth of erosion during certain periods can be somewhat definitely determined.

Referring to the erosion of the gold-bearing rocks of Nova Scotia, Mr. E. R. Faribault says: " Extensive denudation has worn away the folded measures to the present level. Some of the sharpest and highest folds have been truncated to a depth, as far as known, of over eight miles, exposing at the surface a section of gold measures over five miles in thickness."*

From recent studies in Central Pennsylvania, R. T. Chamberlin has shown that a thickness of at least between three and four miles has been eroded since later Paleozoic times.**

According to Dana and other writers the Appalachians have lost by denudation much more material than they now contain. Faults, in which one side was left standing 10,000 feet or more above the other, have been so levelled off that there is no evidence of the fault in the surface features of the country.†

In South Africa it has been found that over ten thousand feet of rock were removed during one comparatively short period, the interval between the Jura-Trias. Since erosion to this extent has taken place in such an interval, how vast must be the erosion on surfaces, such as those of northern Ontario, that have been exposed throughout a large part of geological time!

Climate in Past Ages

The sedimentary rocks furnish evidence of changes in climate in the region. The older sedimentary material, especially iron formation and crystalline limestone, which is believed to represent the Grenville series of southeastern Ontario and to have had a great thickness, indicates a warm or at least a comparatively mild climate. Thick deposits of limestone would not be formed in cold water.

The character of the sediments of the Temiskaming series also do not indicate a cold climate. On the whole, those of the Cobalt series indicate a climate, probably not greatly unlike that of the present; although there is considered to be evidence of the deposition of some of these rocks by ice action.

The limestones of Clinton and Niagara age show that at that time the climate was mild.

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*Jour. Can. Min. Inst., Vol. II., 1899, p. 121.
**Journal of Geology, Vol. XVIII., 1910, pp. 242-3.
†Dana, Manual of Geology, 3rd Edition, p. 653.
‡The Geology of Cape Colony, Rogers and Du Toit, p. 413.

The record, from the time of the deposition of these limestones to the Pleistocene ice age, is lacking, owing to the surface having been exposed above the sea for much the greater part at least of the vast interval, during which it has been subjected to denudation.

Economic Effects of Erosion

In so far as concerns the cobalt-silver deposits, only two of the four great periods of erosion described need be considered. Doubtless, however, vast quantities of other mineral deposits of economic value were removed by erosion in the two earlier periods. There is evidence, for instance, that iron formation was present on a large scale before the earliest period of erosion. Many deposits that might have become great iron mines were in all likelihood removed. Then the Porcupine and other gold deposits of the region appear to be genetically connected with the Lorrain granite. This rock, as well as the older series of the district, was deeply eroded during the time that the sediments of the Cobalt series were being deposited. Hence the gold veins have doubtless had much of their upper parts cut off. It may be noted that the ores now found in the veins give evidence of a deep-seated origin. Deposits of chalcopyrite, pyrite and galena, now of small extent in the district, suffered like those of iron and gold.

All of the mineral deposits mentioned have of course been subjected to erosion during the last two periods, viz., that between the pre-Cambrian and Niagara, and that of great duration between the Paleozoic and the present time.

While the cobalt-silver deposits are later in age than the two earlier periods of erosion, they or the rocks in which they occur, have been exposed to the effects of denudation during the greater part of the later two periods. Probably these veins or deposits did not extend to the surface, as it existed at the time they were formed. Erosion has, however, removed the rocks that lay above, or in which certain veins or parts of veins were enclosed, and great quantities of ore have been removed. There is evidence of this even in the boulders of rich ore that have been found in glacial deposits to the south of the productive area (see page 32).

While the rocks in which the veins are found were subjected to erosion during part of the time that elapsed between the pre-Cambrian and Niagara, they were protected for a time by submergence and a covering of Paleozoic rocks until these were removed in the vast period of erosion that has followed the Niagara.

REGIONAL DISTURBANCES

From the geological maps and the plan, showing the distribution of the veins at Cobalt, which accompany this report, it will be seen that while the belts of the fragmentary rocks strike approximately northeast and southwest, as for example the belt along the railway at Cobalt and the Glen and Kerr lake belt, the majority of the veins have a strike different from this. It would also appear that the strike of the veins in this area has little connection with the disturbance or disturbances which caused the great majority of the larger rivers and chains of lakes in the district to follow one or other of two well defined directions.

A glance at a general map, such as the "Map of Part of the District of Nipissing," published by the Department of Lands and Mines of Ontario, will convince the reader that the system of water courses in the district is a truly remarkable one (Fig. 51). The Nipissing and Temiskaming map sheets published by the Geological Survey, Ottawa, show the system to hold over a still larger district. The chief water courses, as the maps show, follow either a northeast and southwest, or a northwest and southeast direction. While both of these courses are indicated clearly on the maps, the latter is the more prominent.

N.W.—S.E. Water System

The Temiskaming and Northern Ontario Railway from lake Temiskaming to North Bay junction, on the main line of the Canadian Pacific Railway, has naturally been constructed along the line of least resistance, or in other words, it has been built for the most part along a line of depression in order to avoid costly rock cuts. The map shows that this road practically parallels, running in a northwesterly direction, the Ottawa river and lake Temiskaming for the first 90 miles or more of its course, to the crossing of the Montreal river at Latchford station, the railway being 15 or 20 miles to the westward of the Ottawa. At Latchford the railway turns northeastward and runs for 12 or 14 miles, parallel with the second great system of water courses, to Haileybury on lake Temiskaming. The direction followed by the railway for the first 90 miles of its course proves that there is a line of depression here, parallel with the Ottawa river and lake Temiskaming, although it is not indicated by water courses on the map along the greater part of the route.

Continuing northwestward from Wabi bay, the northwest corner of lake Temiskaming, and in line with the direction followed by the main body of this lake and the Ottawa river for about 75 miles, there is a water course, Wabi creek, which flows southeast for about 15 miles. In line northwestward from this point on Wabi creek the map of Nipissing does not show any prominent water course in a direction northwest and southeast for about 15 miles, although two branches of the Blanche river cross this space on the map in a direction northeast and southwest, parallel with the other great system of water courses. Fifteen miles in line northwestward of that part of Wabi creek referred to, the lake Temiskaming-Ottawa river line is continued northwestward by what is here known as the south branch of the Blanche river. For 15 miles northwestward here the river is represented by lake expanses, Long and Kinogami lakes, and for 15 miles above the upper of these lakes the river is ascended in a northwest direction to the limits of the map of Nipissing, to which reference has been made.

The length of the line followed northwestward from Mattawa by the series of water courses mentioned—Ottawa river, lake Temiskaming, Wabi creek, Long and Kinogami lakes and the upper part of the south branch of the Blanche river—is approximately 135 miles.

It will be seen, however, that there is a bend in lake Temiskaming near the point where the Montreal river enters it. The lower part of the lake and Ottawa river are therefore more in line with the Montreal river than with Wabi creek.

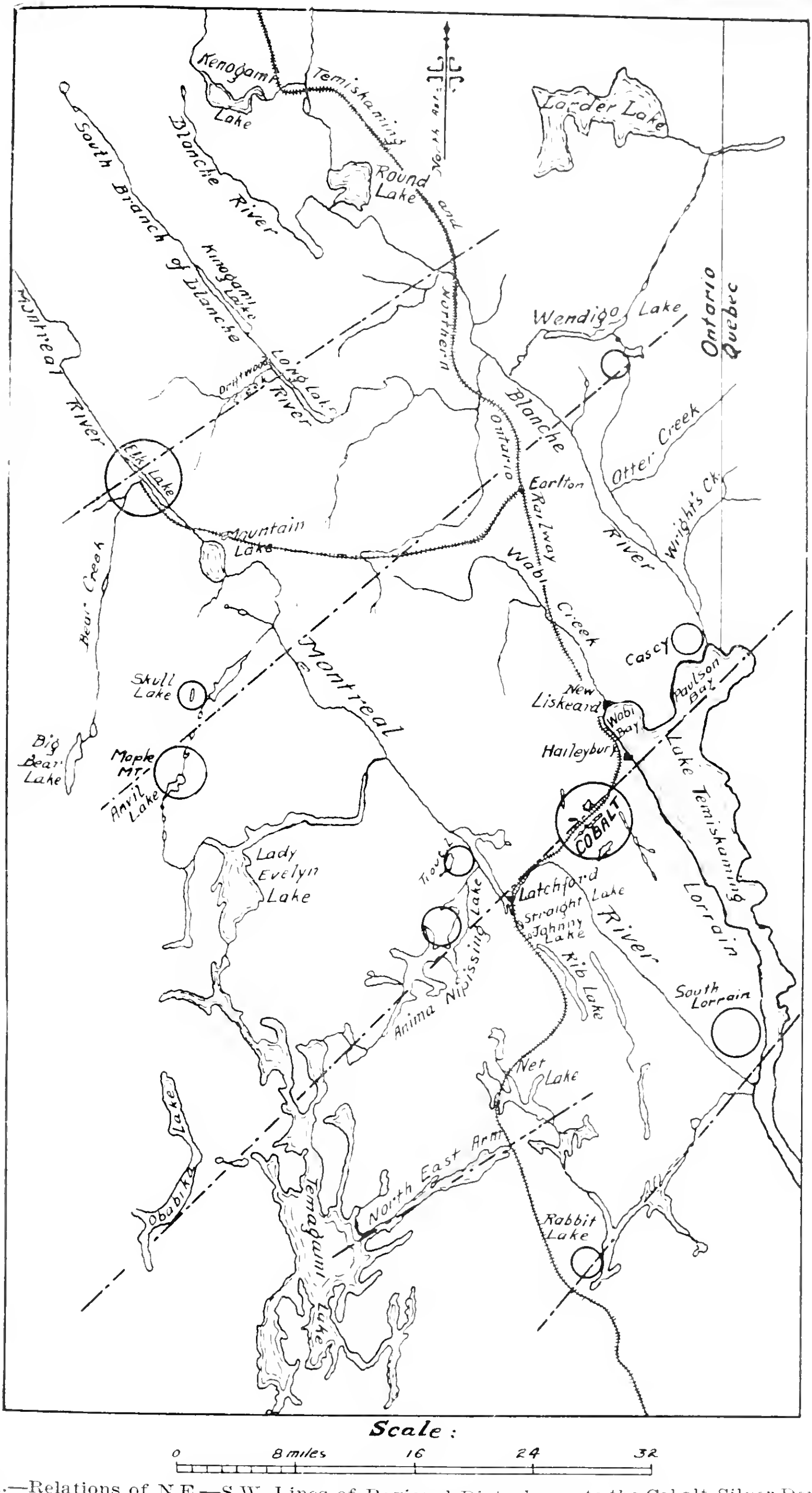

Fig. 51.—Relations of N.E.—S.W. Lines of Regional Disturbance to the Cobalt-Silver Deposits. Rabbit Lake—South Lorrain; Anima-Nipissing—Cobalt; Anvil Lake—Wendigo Lake.

The Blanche river enters the northeastern expansion of lake Temiskaming and the main stream and Round lake branch of this river follow a northwest line for a distance of 35 or 40 miles. This northwest axis of the Blanche lies parallel with the Wabi creek-lake Temiskaming axis, and 9 or 10 miles to the northeast of it.

A third water course which shows a striking parallelism to the two described is that of the Montreal river, which lies 10 or 11 miles southwest of the northwest axis of the Ottawa river. From the railway crossing at Latchford station northwestward through Bay lake and the townships of Auld, Barber, James, to the edge of the Nipissing map, the line of the river holds its northwestward course for over 50 miles. Southeastward from Latchford station the line of weakness, if we can so call it, is continued through Straight, Johnny and Rib lakes for 9 or 10 miles. It will be seen that in the township of Barber and immediately below Latchford station, for example, the river changes its course for 3 or 4 miles, here following the direction of the other great system of water courses, that is the northeast and southwest one, but it gets back again into its normal northwest and southeast course.

Immediately east of the cobalt-silver area there is a chain of small lakes—Cross, Kirk, Chown and Goodwin—with connecting streams, which follows a clearly defined northwest and southeast direction, parallel with the shore of Temiskaming, distant 3 miles to the eastward.

N.E.—S.W. System

The water courses and lake axes which lie in a northeast and southwest line are not so prominent on the maps as are the northwest-southeast ones just described; still they form a not indistinct system, and, as indicated by Fig. 51, they seem to have an important, but as yet little understood, relationship to the cobalt deposits of not only Cobalt proper, but of those of Rabbit lake 30 miles to the south, Casey township 15 miles to the northeast, South Lorrain to the southeast, and others. If a line be drawn on the map from near the mouth of the Quinze river, at the northeast extremity of lake Temiskaming, southwestward to Latchford station on the Montreal river, a distance of 22 or 23 miles, and beyond, it will be seen that it follows the main axis of the large northeast bay of lake Temiskaming, and that the longer axis of Cobalt lake lies parallel to it. Several other small lakes—Short, Pickerel and Bass—lie approximately on this line, as does also that part of the Montreal river between Latchford station and Gillies. Farther southward it will be seen that one long narrow arm of lake Temagami and adjacent bodies of water follow a northeast and southwest line for over 20 miles. Rabbit lake, east of Temagami, has one arm 5 or 6 miles in length running in the same direction and another whose axis follows a northwest-southeast line. The two arms of Obabika lake, to the west of Temagami, show a similar relationship, one to the other.

The most striking water course following a northeast-southwest line is, however, the northeast or what is sometimes called the Abitibi branch of the Blanche river. There is a string of eleven lakes here between Wendigo lake, north of the township of Ingram, and the Quebec boundary, a distance of 15 miles. To the southwestward in the townships of Armstrong and Henwood the south branch of the Blanche follows about the same direction. Otter and Wright creeks, which run from the Quebec boundary into the Blanche river, between the head of Temiskaming and Tomstown, flow in a southwest direction.

The plan, Fig. 51, shows that the three occurrences of cobalt ores, viz.: at Cobalt, in Casey township, and those at Anima-Nipissing, are on or near one northeast-southwest line. The occurrence at Rabbit lake and in the township of South Lorrain are on a similar line. Further, the deposits at Anvil lake or Maple mountain are approximately in line with those at Wendigo. Believing that the occurrence of ore is in some way connected with the northeast-southwest lines of weakness the writer advised prospectors to search for deposits in the vicinity of Animanipissing. This resulted in the first finds of cobalt there.

At points where the two systems of water courses join a number of striking V-like turns are shown in lakes and rivers, as for example, those formed by (1) the two arms of Rabbit lake, (2) the northeast arm of Temagami with the main body of the lake, (3) the turns in the Montreal river at Latchford station and at the Sandy portage, (4) the longer axis of Wabi bay with that of Paulson's bay at the head of lake Temiskaming. The angles thus formed appear to be slightly less than a right angle and the V in all but one of the cases mentioned points southward. The axes of the two arms of Obabika lake form an angle greater than a right angle, which points eastward.

Considering the great variety of rocks cut through by the water courses of the two systems, the regularity of the courses over such a large district is remarkable. A few lakes and streams have their longer axis lying in a north and south or in an east and west direction, but they do not form a system comparable to either of the other two.

Origin of the Systems

The preceding notes on regional disturbances were published in the first edition of this report, written in 1904, and in subsequent editions. It may also be well to republish here the following two paragraphs in which predictions, that have now been verified, were made that certain structures are due to faults. As shown, on other pages in this edition of the report, and on the geological sections (Plates I-VI) that accompany it, underground work in the mines has now proved that a fault follows the longer axis of Cobalt lake and extends beyond it. The Niagara limestone in the township of Dymond furnishes verification of the statement that a northwest-southeast fault follows the longer axis of lake Temiskaming.*

"Concerning the origin of the two great systems of water courses little can be said at present. It is impossible to say whether the courses follow fault lines or simply folds. They are doubtless due to regional disturbance in post-Nipissing diabase times. Much of the surface of the country is covered by recent and glacial deposits, and the rocks where exposed present such a complex of igneous and metamorphosed fragmental material, with minor faults and folds, that it will be difficult to prove the existence of what may be called regional faults or folds. It can be proved that slight faulting, at least, has taken place in post-Glacial times.

"At Cobalt lake, which has its longer axis parallel with one of these regional axes, if we may so call them, the beds of the greywacké-slate and conglomerate of the Cobalt series dip towards the lake, as shown at the veins on the Coniagas property and on Cobalt hill, on the Nipissing, location R L 404. The lake, judging from the dip of these rocks, occupies the axis of a syncline. The hills where the dip was observed lie at an elevation, on both locations, of about 100 feet above the railway track at Cobalt station. At the powder house vein, however, on the La Rose, near the foot of Cobalt lake, the slate is seen to be practically horizontal. The vein here referred to is at the base of a cliff, which rises to a height similar to that of the hills across the railway track to the westward on the southern part of R L 400. In the former case, the hill is composed entirely of the greywacké-slate, while on R L 400 the rock is conglomerate of the same series. It would thus appear that the railway here follows approximately a line of fault. . . . . . . There may thus be a fault here parallel with the main axis of the synclinal fold and Cobalt lake. The strike of the main vein of the La Rose mine, J S 14, near the foot of Cobalt lake and that of the McKinley-Darragh vein at the head of the lake are approximately parallel with the main axis of the lake." . . .

Age and Character of Faults

Faults, with throw of a few feet at most, and joints are numerous in the rocks in which the ores are found at Cobalt. Fig. 12 of a part of the Cobalt vein, one of the first four found in the area, near the shore of Cobalt lake on the Nipissing property, illustrates the character of the faults with small displacement. Many faults were

*Eng. and Min. Journal, Sept. 30, 1911, p. 645.

found in working the main vein on La Rose property. Most of the small faults, like those of the greater one through Cobalt lake, are of the reverse class, the fault plane in the small ones being nearly horizontal.

In the mines few drifts are run that, for a part of their course at least, have not one smooth wall indicating a fault or a joint.

Even the fragmental rocks, as explained in the description of the Cobalt greywacké on another page, frequently possess a columnar structure. The veins often branch, forming stringers that run around the columns.

Faults of various ages are to be seen. At Cobalt certain faults in the Keewatin are older than the Cobalt series of conglomerate and greywacké, and may antedate the intrusion of the Lorrain granite. Others were doubtless produced at the time this intrusion took place. Faulting also likely occurred at the time of the eruption of the Nipissing diabase.

It is interesting to learn from the valuable, recently published report of Dr. A. C. Lane on the Keweenawan of Michigan, distant four hundred miles or more to the west of Cobalt, that regional disturbances of post-Niagara age also affected the rocks of that state which in many respects resemble those of Cobalt.*

A fault like that through Cobalt lake is younger than any of the pre-Cambrian rocks of the area, and may be even of post-Niagara age (Plate V). The northwest-southeast fault that is believed to run approximately parallel to the west shore of lake Temiskaming appears to be later than the Niagara limestone, since a strong fault is seen in this rock to the northwest in the township of Dymond, being apparently a northwestern part of the lake Temiskaming fault. Movements may have recurred along a great line of this kind during a vast interval of time. Veins formed during earlier movements might be reopened during later ones, and there would be a tendency to form parallel fissures.

Economic Bearing of Faults

The production of cobalt-silver ores has come from what may be called the upper rocks of the pre-Cambrian, or those which are in close association with the diabase sill, in distinction from those which lie at a depth below the sill. In an area which has been subjected to such intense erosion as has Cobalt, it is not remarkable to find that, in many places, the pre-Cambrian rocks that overlay the sill, or formed its hanging wall, together with the sill itself and a considerable thickness of its lower wall, have been removed. Under such conditions of erosion it is but to be expected that the upthrow sides of faults, or those that stood at a considerable elevation above the downthrow side after the dislocation had taken place, should have suffered the most. In the process of base levelling the upthrow side has in many cases been worn down to the level of the downthrow side. The result has been that the ore-bearing rocks, the diabase sill with the rocks on its upper wall and those for some distance below it, have been completely removed, exposing rocks that lay a considerable distance below the sill.

In the case of the downthrow side of faults the opposite effect has been produced, and a protective influence has been exerted on the ore-bearing rocks. Along the west, or downthrow, side of the fault that extends through Cobalt lake the rocks of the Cobalt series, that formed the foot wall of the diabase sill, have a much greater thickness than have the rocks of this series on the opposite side of the fault line. This has resulted in the preservation of parts of rich veins, on the downthrow side, which have added much to the value of the Cobalt Lake and McKinley-Darragh mines, whose workings are under the lake.

Faulting also appears to have an important economic bearing in considering the practical absence of rich cobalt-silver deposits on the Quebec or eastern shore of lake Temiskaming as contrasted with the abundance of these ores on the Ontario side of the lake, which here forms the boundary between the two provinces. The quartz-

*The Keweenawan Series of Michigan, Mich. Geol. Survey, 1911.

diabase, so characteristic of the Ontario mining area, is practically absent on the Quebec side of the lake. Moreover, the rocks that occur in greatest volume on the Quebec side are those which are older than the Cobalt series, viz.: Lorrain granite and Keewatin, although there are exposures of Lorrain arkose and quartzite. These last mentioned rocks, where they rest on granite, may be contemporaneous with the lower part of the Cobalt series.

From what has been said in the preceding paragraph it would appear that the Quebec side of the lake represents the upthrow side of a great fault, and that in the process of base levelling the ore-bearing rocks, the diabase sill with the rocks on its upper and lower walls, have been destroyed by erosion.

The numerous minor faults that have been studied in the Cobalt area are practically all of the reverse type, as is also the larger fault which traverses the rocks below Cobalt lake. Hence the fault that followed the line, now represented approximately by the western shore of lake Temiskaming, may be of the same character. Otherwise strata in the face of the cliff of Niagara limestone, in the township of Dymond, which dip to the east, represent normal faulting and do not agree with the theory that the Quebec side of the lake is on the upthrown side of the fault.

The character of the faulting in the region is, however, somewhat complex, but judging from what have been called the lines of weakness, or the direction in which lie the longer axes of the lakes and the course followed by the rivers, and from the direction of the known fault lines, the faults are in a direction either northwest-southeast or northeast-southwest. This would bring about the formation of great blocks, as illustrated in the accompanying diagram (Fig. 51).

The northwest-southeast faults appear to be of greater magnitude than those following a northeast-southwest course. It is not known whether the two fault systems are of the same or of different ages. Probably they are of similar age, and recurrent movements have taken places along both systems.

THE COBALT-SILVER VEINS

The relations of the veins to the rocks of the Cobalt area are illustrated in the colored cross-section, "Ideal Restoration of Rocks and Veins at Cobalt" (Plate IV), that accompanies this report. They are also shown in Fig. 7, page 5.

The distribution in the area of the important veins that had been discovered up to 1907 is to be seen on the geological map, scale 400 feet to 1 inch, that accompanied the third edition of this report. The uncolored map, scale 800 feet to 1 inch, of a part of the area shows the veins that were known up to a year ago. Two or three important veins, notably one under Cart Lake, have been discovered since that time.

The minerals found in the veins, and their age relations, are described on preceding pages.

Fissures and Joints

"It is not always possible, in a shattered rock, to discriminate between joints and those lines of division to which the term fissure is more usually restricted. Many so-called fissures may be merely enlarged joints."* This holds true in the cobalt-silver area.

Fig. 52.—A typical silver-cobalt vein, outcrop on the Coniagas. The head of the hammer shows the width.

While the openings occupied by some veins, or parts of veins, can be called fissures, there are many more to which the writer is inclined to apply the term joint. The openings in the greywacké and conglomerate are in many cases connected with columnar jointing in these rocks. A vein may occupy a distinct fissure-like opening for some distance, then it may split up, the stringers thus formed running around columns out of the former course of the vein and coming back some feet ahead into the line first followed. The columnar jointing is well shown in the rock cut along the railway a short distance south of Cobalt station. Several of the trenches, 20 feet or more in depth, from which ore has been extracted, illustrate the same phenomenon.

The dip of the great majority of the veins is vertical. As shown by the maps, there is no uniformity in the strike.

*Geikie, Text Book of Geology, p. 688.

Relation of Wall Rock to Ore

The productive veins, as the maps and cross-sections show, are found in three series of rocks, viz.: the conglomerate and other sediments of the Cobalt series, the Nipissing diabase sill, and the Keewatin complex. But eighty per cent or more of the ore has come from the Cobalt series. The chief reason for this greater productiveness is due to the fact that these rocks fractured more readily than did the diabase or the Keewatin.

There appears to have been no difference in the precipitation of ores due to physical-chemical influences of the country rocks Precipitation seems to have taken place as readily in rocks of any one of the three series mentioned in the preceding paragraph as in the others.

Judging from the way in which silver is found in the minutest cracks in granite boulders of some of the conglomerate near the veins, this ore, at least, was precipitated no less readily in acidic rocks than in basic ones. With the exception of these boulders, there are few opportunities afforded of observing the relations of the ore to granite. But in the Temiskaming mine, a few hundred feet below the surface, narrow dikes of Lorrain granite intrude the Keewatin and are cut across by the vein. The surface of the granite is plated with native silver.

The occurrence of rich silver ore depends on the character of the openings in the rocks now occupied by the veins, on whether the veins have been affected by secondary disturbances, and on the proximity of the openings to the diabase sill. Naturally it would be expected that solutions would work upward through the openings in the hanging wall above the sill more readily than downward into the foot wall. Unfortunately owing to the excessive erosion to which the district has been subjected, there is little of the hanging wall of the sill left in the productive area at Cobalt. But of the veins thus far worked the two or three that occur in the hanging wall are productive to the greatest depth reached in the area.

In the foot wall of the sill, or what was the foot wall before erosion took place, the rich or merchantable ore is limited as to the depth to which it extends. This depth below the sill is variable, depending on the character and strength of the fissures. Rich ore descends to a less depth in narrow, more irregular fissures than in wide ones.

As has been said previously, much the greater part of the ore has come from veins in the fragmental rocks of the Cobalt series in the foot wall of the sill. These veins, on reaching the contact of the Cobalt series with the underlying Keewatin, either end at the contact, or split into stringers, or continue down into the Keewatin. In many cases the rich ore disappears when the veins penetrate the Keewatin. On the other hand, a few veins in stronger fissures have been found to be productive in the Keewatin, that, before erosion, lay beneath the sill.

The diabase sill, like the Keewatin, has thus far been found to contain but few rich veins in the Cobalt area. In the veins both in the diabase and Keewatin rocks, ore is found to occur more irregularly distributed than in those of the Cobalt series. In other words, it tends to occur in bunches.

The best veins that have been worked in the diabase are one on the Kerr Lake property and one on the O'Brien. Of those in the foot wall of the sill the best vein in the Keewatin has been No. 26 on the Nipissing. The veins on the Temiskaming and Beaver properties are in the Keewatin of the hanging wall of the sill, and descend into the sill itself.

Secondary Disturbance of Veins

In the case of a vein which passes from the Cobalt series into the Keewatin and carries high silver values in the former and not in the latter, the variation in values is to be accounted for by the fact that there have been two periods of deposition of the ore minerals. The first minerals to be deposited after the cracks were formed were essentially the cobalt-nickel arsenides. After these minerals were deposited there was a slight disturbance of the rocks, and the veins were slightly fractured and opened, giving an opportunity for the deposition of the silver minerals which were then per-

colating through the rocks. The Cobalt conglomerate and slate-like greywacké, being not highly metamorphosed and lying on the Keewatin or in contact with the diabase, were affected by the secondary disturbance, while the great mass of tough Keewatin rock for the most part escaped the disturbance and the veins in it were not fractured so as to give access to the silver solutions. Where Keewatin veins lay near a diabase contact they were not only in a better position to be affected by the secondary disturbance, but they were also nearer the source of the solutions which appear to have come from the diabase magma.

Dimensions of the Veins

In width the more characteristic veins probably average about four inches. One of the first veins to be worked, the Trethewey, had a maximum width of about eight inches. Another of the earlier discovered veins, that on the hill near the shore of Cobalt lake

Fig. 53.—An underground view in La Rose, showing parallel veins

on the Nipissing property, had a width of fourteen inches, but it was not of economic importance as a source of silver. An analysis of the ore is given on page 17. The first level on the main LaRose vein followed what may be called more properly a system of veins, three or four roughly parallel veins being at times exposed in the level (Fig. 53). Numerous, small, nearly horizontal faults were found in the veins, which were frequently thrown beyond the face of the level. Where the whole vein system was exposed, the total width of ore averaged slightly over one foot. The length of La Rose main vein with its continuation on the Right of Way property is about 1,000 feet. One of the side or cross veins, No. 3, on LaRose has a length of about 900 foot.

Usually the veins are much shorter. Certain veins that average not more than an inch in width have a length of one hundred feet or more.

The complex character of the veins on some of the properties is shown in the plans published in the annual reports of certain of the mining companies, e.g. the Coniagas, where wide stopes are worked which include several narrow veins with frequently varying strikes.

The depth of the veins, or the productive parts of them, is variable, depending on

whether they continue downward in one class of rock or encounter rocks of different classes, on the strength of the fissures, and on the distance of the ore bodies, in the Cobalt series and the Keewatin, from the diabase sill.

One of the first veins to be worked had a depth, at the point where the shaft was sunk, of sixty feet in the Cobalt series and came to an end when the Keewatin was reached. Other veins have been worked to a depth of two hundred feet or more in good ore, but most of them are productive to lesser depths.

Even in the Cobalt series, where the thickness is greater than usual, the rich ore in certain cases has been found to disappear before the underlying rocks are reached.

As has already been said, the veins that have been found to be productive to the greatest depth lie in the hanging wall of the diabase sill. Little of this wall is left at Cobalt, most of it having been removed by erosion, and the great majority of the veins are in the foot wall, a few being in the sill itself.

Former Vertical Extension of Veins

Certain writers have expressed the opinion that veins of the Cobalt area, that outcrop at the surface or occur immediately below the drift covering, represent the narrower, lower parts of wider veins that extended to or towards the original surface. There is no justification for the holding of such an opinion. The few veins that have been worked to a depth of a few hundred feet in rock of one series give no indication of becoming narrower below, althougth, when the veins are in the foot wall of the sill, the ore tends to become less rich, as the vertical distance below the sill or the eroded part of it becomes greater. Moreover, "blind" veins, or those which do not reach the present surface of the rock, have been found. These veins have the same character, as regards width and mineral content, as those which are exposed at the surface.

Briefly, it appears that after the intrusion of the diabase, fissures and cracks were formed in the rocks of the hanging wall and in those of its foot wall, and in the sill itself. The openings in the upper wall probably extended a considerable distance upward beyond the sill, but there is no evidence that they reached the surface or that they were wider in the parts that have been eroded.

As already said, some of these fissures in the upper wall extended downward into the sill itself, e.g., veins on the Temiskaming, Beaver, and Nova Scotia.

Then there are veins, e.g., that on the Cobalt Central property, which have been worked at the surface in the diabase and followed downward into conglomerate and greywacké which at times lie beneath the sill.

Again blind veins are found in the Cobalt series and in the Keewatin where the sill has been eroded.

There are also blind veins, e.g., one that was worked two or three years ago under Peterson lake and one on the Silver Leaf property, that lie in Keewatin beneath the sill. These veins run upward to the lower face of the sill but not into it (Fig. 7, page 5).

Richness of the Ore

The comparatively small width of the veins caused doubt in the minds of some of the first engineers who visited the area, after the discovery of ore was reported, as to the economic importance of the veins. The richness of the ore and the multitude of veins have, however, more than compensated for the narrowness.

For some time after mining began at Cobalt the ore was shipped to the sampling works of Ledoux and Company. In an interesting description of the character of the ore Dr. A. R. Ledoux says that the shipment that carried the highest values contained 7,402 ounces of silver to the ton, the next in order being 6,909, 6,413, 6,163 and 5,948 ounces to the ton. The average percentages of other metals in the 366 carload lots sampled by this firm were: cobalt 5.99, nickel 3.66, arsenic 27.12.

The great richness of the ore extracted from one of the first veins worked at Cobalt is shown by a shipment made from the Trethewey mine, one carload of ore,

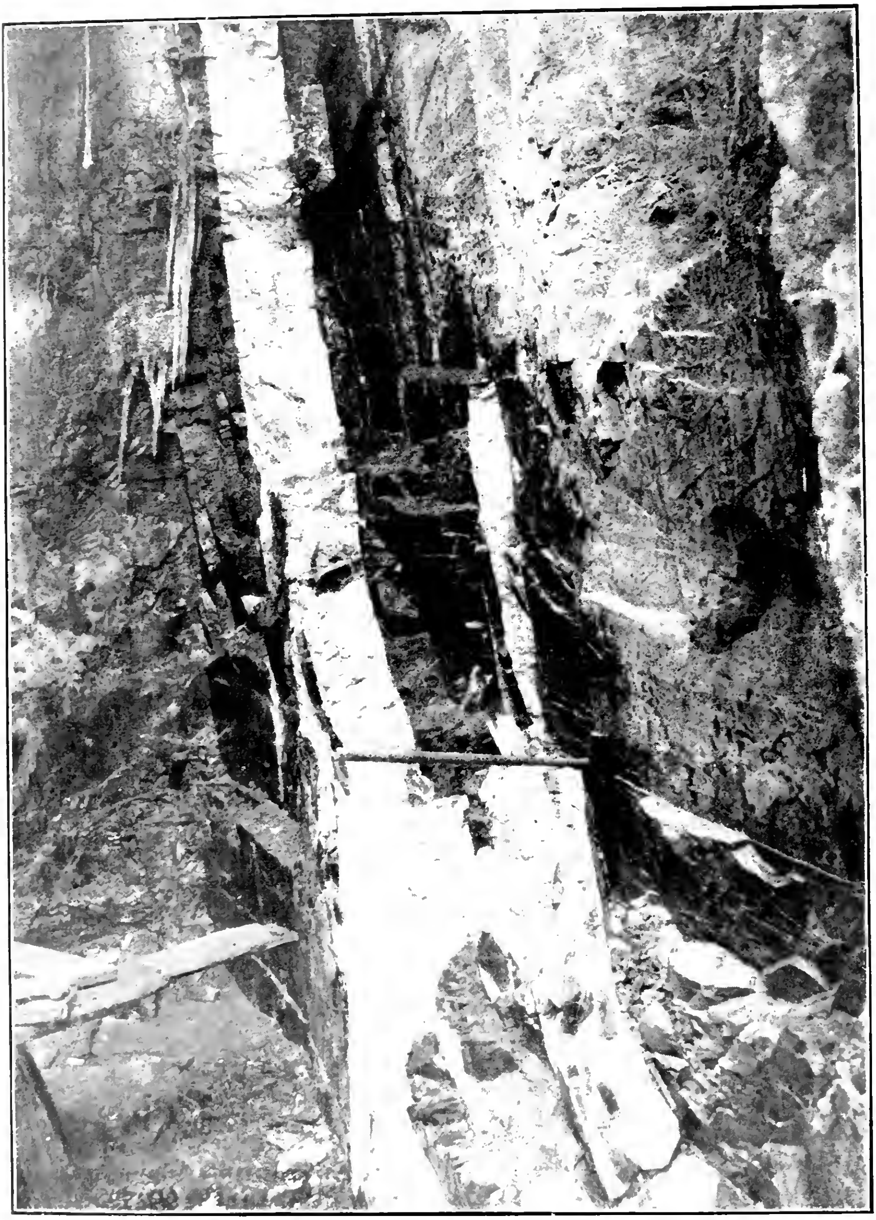

Fig. 54.—Carson vein on Crown Reserve property, Kerr lake.

containing thirty tons, being sold for between $75,000 and $80,000. Another shipment, consisting of fifty tons of ore, gave on analysis approximately the following percentages of metals: arsenic 38, cobalt 12, nickel 3.5. The shipment contained 180,000 ounces of silver. An open cut or trench, about 50 feet long and 25 feet deep, on the vein produced approximately $200,000 worth of ore. The maximum width of the vein was not over eight inches.

Certain shipments during later years have exceeded in value the early shipments from the Trethewey.

Speaking of the high grade ores of Cobalt, Mr. R. B. Watson says: "A typical ore carries 10 per cent. silver, 9 per cent. cobalt, 6 per cent. nickel, and 39 per cent. arsenic; the rest is lime, silica, and smaller amounts of antimony, iron, sulphur, tellurium, etc."*

The most productive vein in the area has been that known as the Carson. This vein on the Crown Reserve property, together with its extension on the adjoining Kerr Lake property, has produced about 14,000,000 ounces of silver, all the ore having come from above the 200-foot level. It has been estimated that the total production, including that already mined, from this one vein will be 20,000,000 ounces or more.

The richness of the ore in various mines in the area is also well indicated by what it has cost, on the average, to produce an ounce of silver. In 1911, for example, the cost per ounce, including mining and all other expenses, given in the annual reports of certain companies was: at the Crown Reserve 10.761 cents, at the Coniagas 8.8, at the Nipissing 13.95, and at the Kerr Lake 14.69.

The ratio of dividends paid by the companies to the total value of the ore produced, given on other pages of this report, shows in a more general way the character of the ore (page 37).

Probable Total Number of Productive Veins

In an interesting paper, Mr. Geo. R. Mickle has attempted to estimate the number of productive veins that the Cobalt area will have furnished before its productivity in silver ceases.†

The quotations below are taken from this paper:—

"In the following estimate certain arbitrary standards are adopted for the purpose of making definite calculations. Veins that have a certain minimum yield in ounces are called productive. It is obvious that the line must be drawn somewhere; it would be absurd to consider a vein that yielded a few sacks of ore as productive, and as it was desirable to compare this district with others where any vein with only a trifling yield would probably be lost in the records, the minimum output of a productive vein is assumed in the following calculation as 75,000 ounces.

"Up to July, 1911, there appeared to be 111 veins that could be considered productive on this basis; these were distributed among the geological formations as follows:

Huronian (Cobalt series)	86	veins	or	77.5%
Diabase	12	"	"	10.8%
Keewatin	13	"	"	11.7%
	111	veins	or	100.0%

"If the same vein extended into two different formations it was credited to the one out of which the greater part of the silver was obtained. In 1907 at the same time of the year the writer gave the distribution as:—(Vol. XIII, Jour. Can. Min. Inst.)

Huronian (Cobalt series)	53	veins	or	80.3%
Diabase	7	"	"	10.6%
Keewatin	6	"	"	9.1%
	66	veins	or	100.0%

*Eng. and Min. Journal, Dec. 7th, 1912, "Nipissing High Grade Mill, Cobalt."
†The Probable Total Production of Silver from the Cobalt District, Jour. Can. Min. Inst., 1912.

"Four years of energetic and skilful prospecting have not altered the relative number of veins in the different formations. The productivity, however, of the veins in these different rocks is not the same. Up to the present (i.e., July, 1911) the yield from the diabase has been approximately 7.55 million oz. from 12 veins, or 629,000 per vein, or 7 per cent. of the total production. The Keewatin with 13 veins has produced 11.7 million oz., or nearly 1 million per vein, or 10.85 per cent. of the total. This includes whatever silver was obtained in the Keewatin from veins classed as Huronian but extending into the Keewatin. The balance, or 88.55 million oz., has been derived from the Huronian, with 86 veins, or a little over 1 million oz. per vein and over 82 per cent. of the total production. According to the writer's estimate, when all veins at present known are exhausted, the Huronian veins will have produced slightly under 2 million oz. per vein, or 86.6 of the total, leaving 13.4 per cent. to be distributed between the diabase and Keewatin. It is plain, therefore, if the amount of silver in the Huronian veins can be approximately determined, even a serious error in the estimate of the other veins cannot vitiate the result very much.

"The total yield from the discovered veins should be 206.4 million ounces.

"Multiplying the average thus obtained by the probable number of veins yet to be discovered, viz., 21, gives over 35 million ounces (viz., 35.5) as the production from the undiscovered veins, giving thus a probable total of silver from all sources of 242 million ounces."

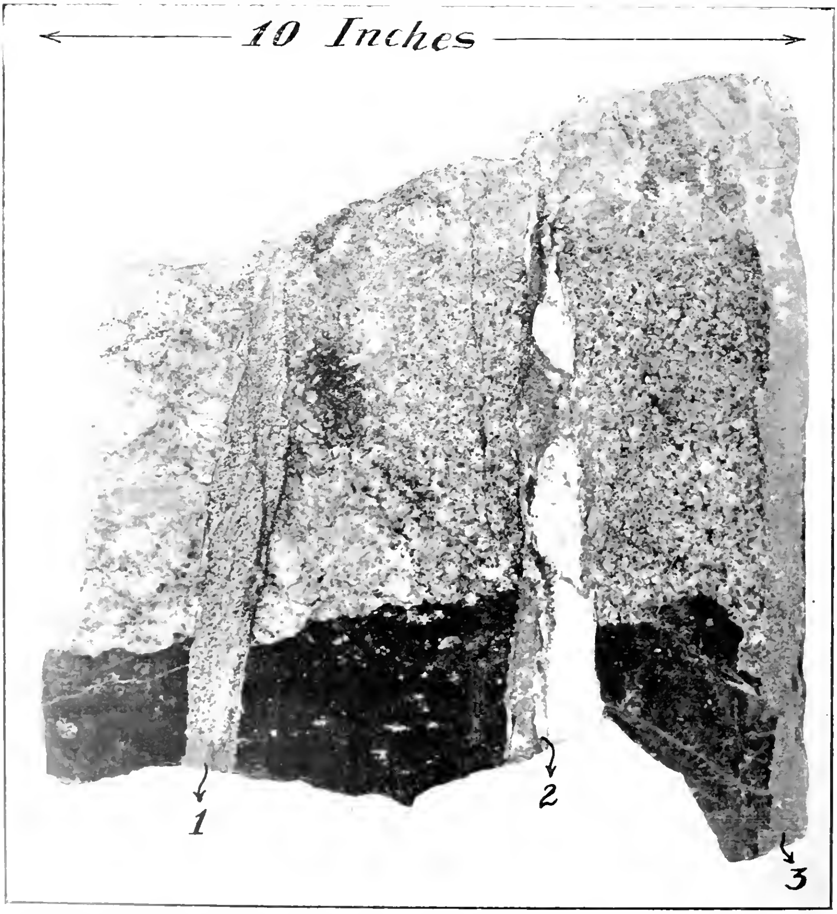

Fig. 54. Three veins in light-colored boulder of granite from conglomerate of Trethewey mine. 1 contains smaltite and native silver; 2 has the same minerals with considerable white calcite; 3 is essentially smaltite.

DISTRIBUTION OF COBALT ORES IN THE DISTRICT

From the following notes it will be seen that cobalt minerals are widely distributed over the district (Figs. 22, 51.).

Outside of the small area of about six square miles that lies adjacent to Cobalt station, the most important mines that are, or have been producers of cobalt-silver ores, lie in somewhat widely separated localities. They include two or three in a part of the township of Bucke, four miles to the northeast of Cobalt, one or two which are now important producers in the township of Casey, fifteen miles to the north, a similar number in the township of South Lorrain, fifteen miles to the southeast, and those near Elk Lake and Gowganda, 40 to 60 miles a little north of west from Cobalt. Small shipments were also made from the vicinity of Maple mountain, in Whitson township, thirty miles west of Cobalt. These outlying areas are described on following pages.

Native silver has also been found with cobalt bloom in veins carrying a high percentage of barite, and a little fluorite, in the township of Langmuir, near Porcupine, one hundred miles northwest of Cobalt. A description of these veins by Mr. A. G. Burrows is given in Chapter II.

As showing the still wider distribution of cobalt, or cobalt and silver ores in Northern Ontario, reference may be made to the discovery of cobaltite and native bismuth in the township of Otter, north of the town of Thessalon, about 190 miles southwest of Cobalt, described in Chapter II. of this report, and to the discoveries made many years ago of similar ores to those of Cobalt in small quantities on Michipicoten Island, Lake Superior. The Silver Islet deposit and others near the north end of Lake Superior are referred to in Chapter III. These are distant about 500 miles from Cobalt. Native silver, as is well known, occurs in the native copper deposits of Michigan. It would seem that the Keweenawan basic igneous rocks of that state, the norite of Sudbury and the Nipissing diabase of Cobalt are genetically connected.

Less Important Occurrences

Thirty miles north of Cobalt, on lots 9 and 10 in the sixth concession of the township of Ingram and elsewhere in the vicinity, quartz veinlets in diabase contain cobalt bloom and smaltite. The area is described on following pages.

Near Anima-Nipissing lake, shown on the accompanying geological map, scale 1 mile to 1 inch, much cobalt bloom has been found. The lake lies on the same line of weakness as Cobalt lake, and is about twelve miles to the southwest of the latter.

On the north end of lot 2 in the third concession of the township of Dymond and on the south end of the lot across the road to the north, cobalt bloom occurs in diabase. The knoll of diabase is overlain around its base by fragmentary rocks which have at one time undoubtedly covered the whole mass of diabase. The lots mentioned lie about ten miles north of Cobalt.

Ore at Rabbit Lake

A peculiar occurrence of cobalt and nickel with gold was discovered in 1905 on Rabbit lake east of Temagami and about 30 miles south of Cobalt station. The outcrop was at the water's edge. The rocks here have been more disturbed and are much more highly metamorphosed than are those in the vicinity of Cobalt station. They appear, however, to belong to the conglomerate-greywacké series. The ore body, about 18 inches wide, is in a zone of fracture. Through the chlorite schist which occupies this disturbed zone is a reddish felsitic material, which, under the microscope, is seen to belong to the fragmental series. Veinlets and impregnations of a grey cobalt-nickel ore occur sparingly in both the chloritic and felsitic material. An analysis of some of the more highly mineralized material gave the following results:

	Per cent.
Arsenic	22.53
Cobalt	8.76
Nickel	6.56
Gold	$8.80 a ton.
Silver	1.10

This unique deposit is of interest since it shows that cobalt-nickel ores are to be looked for so far south of Cobalt station. The Rabbit lake occurrence is about the same distance south of Cobalt station as those of the township of Ingram are north of it, thus showing that the cobalt-nickel ores are distributed over a distance of at least 60 miles in a north and south direction.

Fig. 55.—Part of surface of ore body at Wright mine. Fragments of rock are cemented by calcite, which has weathered, leaving the fragments projecting above it.

Other Silver Ores of the Region Surrounding Cobalt

What has been known for years as the Wright silver mine is on the Quebec shore of lake Temiskaming. It is distant about nine miles northeastward of Cobalt station and lies about seven miles northward of the village of Ville Marie. Some of the rock here is conglomerate, associated with which is porphyry. The latter is similar to rock in Minnesota which has been considered to be of doubtful origin. The ore body lies in a

zone of fracture which penetrates both of the rocks mentioned. Angular fragments of these rocks, sometimes a foot or more in diameter, are cemented together by calcite and galena (Fig. 55). The pure galena has been found to contain from 18 to 24 ozs. of silver to the ton of 2,000 lbs. Iron pyrites is found in small quantities associated with the galena, and is thought to be the source of the trace of gold usually present in the ore.

The writer visited this mine when it was in operation in 1901. The depth of the workings, which in the lower levels had the form of a circular chamber, was said to be about 200 feet. Work ceased shortly after this and has not been resumed. The equipment consists of a concentrating plant, including jigs, tables and other machinery. There is also a small smelter on the grounds. Considerable capital appears to have been expended in experimenting. Whether the deposit could be worked at a profit under proper management does not seem to have been proved. The concentrates were shipped to Europe.

The ore body is unique. An outcrop near the water's level together with the material on the dump afford an opportunity of learning its character. Two or three rather basic dikes are seen near the workings. These are probably of the same age as the fracture zone now occupied by the ore body. The location of this mineral deposit, one of the oldest known in North America, is shown in Fig. 6, Ance à la Mine.

On Lady Evelyn and Cross Lakes

Silver-bearing galena is also found at Cross lake, which lies southeast of lake Temagami, and at Lady Evelyn lake. According to Dr. Barlow there are quartz veins on the Mattawapika, as the last stretch of Lady Evelyn lake, before reaching the Montreal river, is called. These quartz veins are found here on both sides of the lake, and occur at the contact of the intrusive diabase and the banded slate, and in the latter. The minerals are galena, copper pyrites, iron pyrites, and zinc blende.

There is a deposit on an island in Cross lake, which lies immediately east of the south arm of Temagami. The minerals are galena and copper pyrites in calcite. A sample showed the following values per ton: gold \$2.00, silver \$9.20, copper \$4.20, lead \$4.00, or a total of \$19.40.

Galena and copper pyrites have also attracted attention in the vicinity of the Blanche river, especially along the upper part of the north branch.

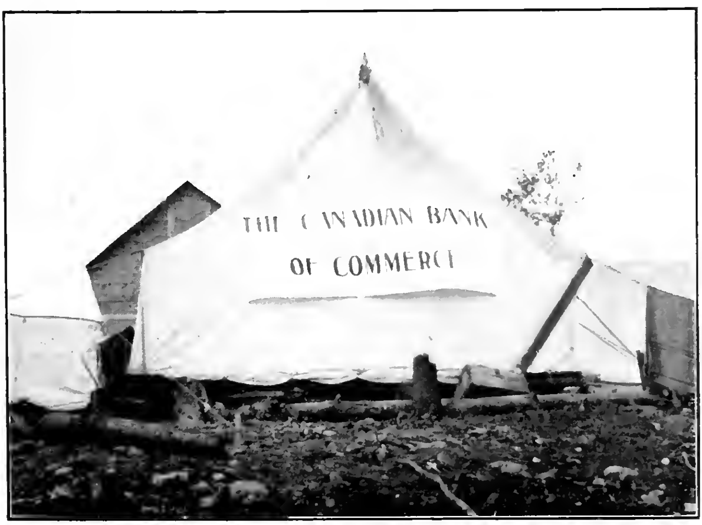

Fig. 55a.—Canadian Bank of Commerce, Cobalt, July, 1905.

PROSPECTING

When the veins were discovered in the vicinity of what is now known as Cobalt, the area was in a virgin state. A large part of the surface was covered with glacial and other loose deposits, and all of it was occupied by green timber. Prospecting was thus made difficult. Only about half a dozen veins were exposed at the surface. Most of those since discovered have been found by trenching through the loose deposits to bed rock. Hundreds of miles of trenches have been dug. The accompanying illustration shows the character of the trenches on a part of the Nipissing property (Fig. 56).

On the Nipissing streams of water under strong pressure have also been employed in removing the loose deposits and exposing the rock beneath.

It may be added that a considerable number of veins have been discovered by drifts and cross-cuts in the underground workings. Some of these are "blind" veins, i.e., they do not come to the surface.

In the notes which accompanied the first edition of our map of the Cobalt area we advised prospectors to pay special attention to the conglomerate areas. This was owing to the fact that the veins then known, with the exception of one or two in the diabase, occur in the conglomerate. Moreover, we believed that the Keewatin being a tougher rock would contain fewer fractures. The edition of the map was published in the spring of 1905, in time for the prospectors who were then entering the field. Much of the area then open for prospecting contained conglomerate. Our advice to the prospectors has been verified, as the great majority of the veins since discovered in the Cobalt area are in the conglomerate. Of course after the conglomerate areas had all been staked the less promising Keewatin and diabase areas became more worthy of attention.

It may be added that when mining began on some of the veins in the conglomerate the writer told the operators that he thought the veins would hold their silver values until the underlying Keewatin was reached, but that he did not think the veins would be productive in the Keewatin. This proved to be the case. It cost some of the operators considerable money to convince themselves of this fact. On reaching the Keewatin they sank and drifted in a vain search for more rich ore. During the time of the "boom" the theory that the Keewatin is less promising than the conglomerate was especially unpopular.

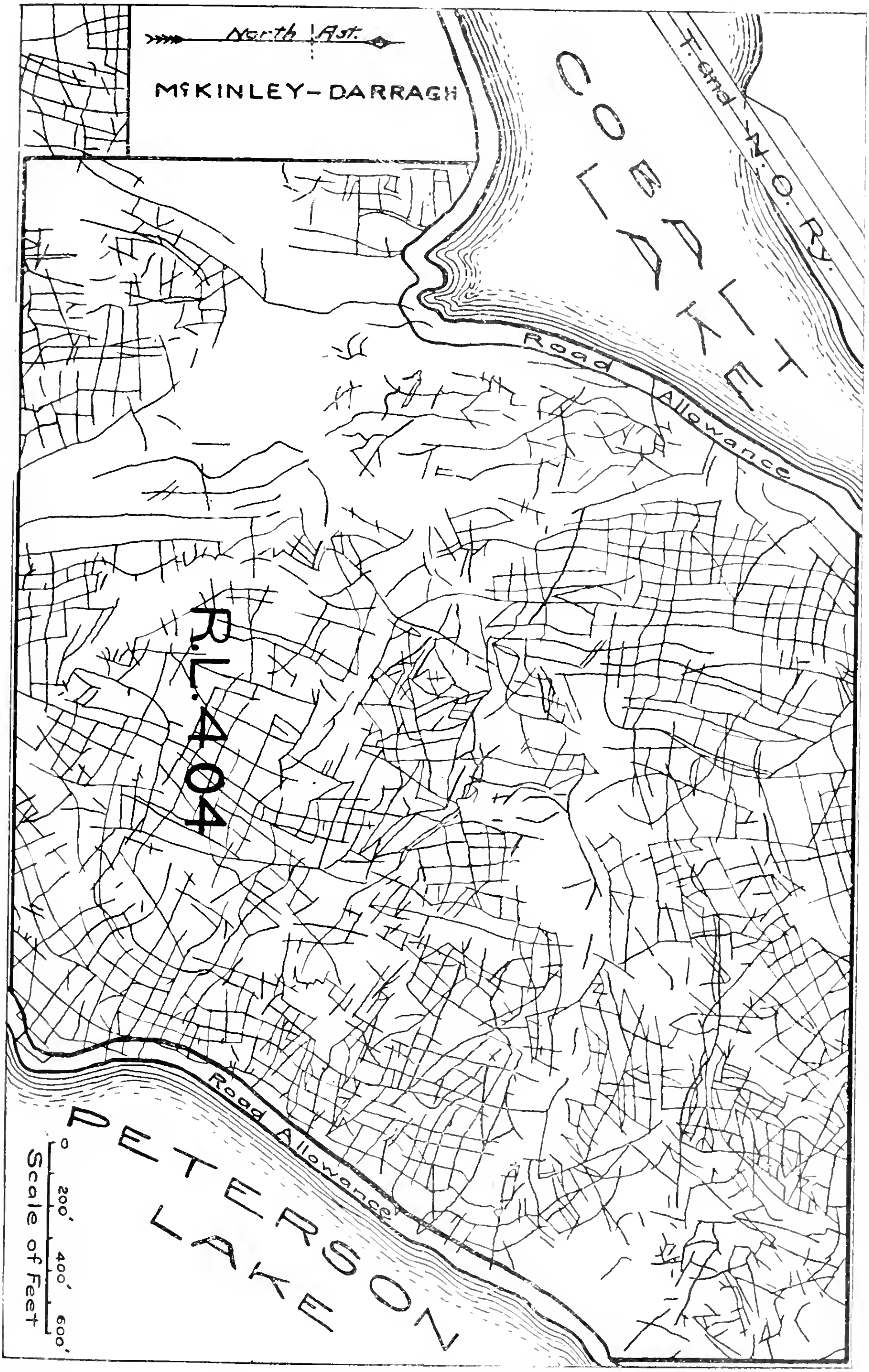

Fig. 56.—Trenches through the loose deposits to the compact rock, illustrating method of prospecting for cobalt-silver veins.

CHAPTER II

The Outlying Cobalt-Silver Areas*

SOUTH LORRAIN SILVER AREA†

By A. G. Burrows

This area first attracted attention in December, 1907, when a very promising discovery of native silver was made on a claim now known as the Keeley mine (H R 19). A rush followed this discovery, and soon almost the whole area was under staking as mining claims.

The central portion of South Lorrain is about sixteen miles southeast of the town of Cobalt. The camp is most easily reached during the open season, by steamer from Haileybury, from which town it is distant about twenty-two miles. Communication is continued during the winter, over a sleigh road on lake Temiskaming. A government wharf has been constructed just north of the townsite of Sixty-six. From the latter place, a good wagon road extends westerly, by way of Loon lake, a distance of three miles, to the Keeley mine. Another road has been built by the Ontario government, just north of the wharf, and opens up another stretch of country. From these roads, old timber roads or trails may be followed to any part of the area. Lumbering has been carried on for years, so that almost all the pine has been removed. During 1908 serious forest fires destroyed much timber which would have been suitable for mining purposes.

Topography

The surface of the country is very rough and hilly, and many small lakes lie in the depressions. The shore line is bold, and the hills rise abruptly from the lake. The hills and ridges are very conspicuous surface features, and are generally found to consist of one geological formation. In consequence, the contacts are usually in the valleys and covered. This fact is well exemplified by a glance at the map, which shows almost all the lakes to lie in contact planes.

In following the road from lake Temiskaming to the Keeley mine, there is almost a continuous ascent. The shaft at the Keeley mine has an elevation of 571 feet and the bridge south of Loon lake an elevation of 323 feet above lake Temiskaming. These elevations are relative to the level of lake Temiskaming on July 15th, 1908, when the water in the lake was higher than the average. The high water elevation of lake Temiskaming is 592 feet above sea level.‡

Classification of Rocks

In this area, the formations are found to conform to the scheme proposed by Dr. W. G. Miller for the Cobalt area. The writer did not, however, see any unconformity between the quartzite-arkose series and the conglomerate-slate of the Cobalt series.

GLACIAL AND RECENT

Boulder-clay, sand, gravel, etc.

Great Unconformity

*The areas described in this chapter include South Lorrain and Casey Townships, Montreal river and Elk lake, with parts of adjacent townships, and Gowganda. Brief descriptions are given of other areas.

†This report on South Lorrain is a revision of that which was published with Part II. of the 18th Report of the Ontario Bureau of Mines. The area is shown on the colored geological map, scale 1 mile to 1 inch, that accompanies this volume.

‡Dictionary of Altitudes, Department of Interior, Ottawa.

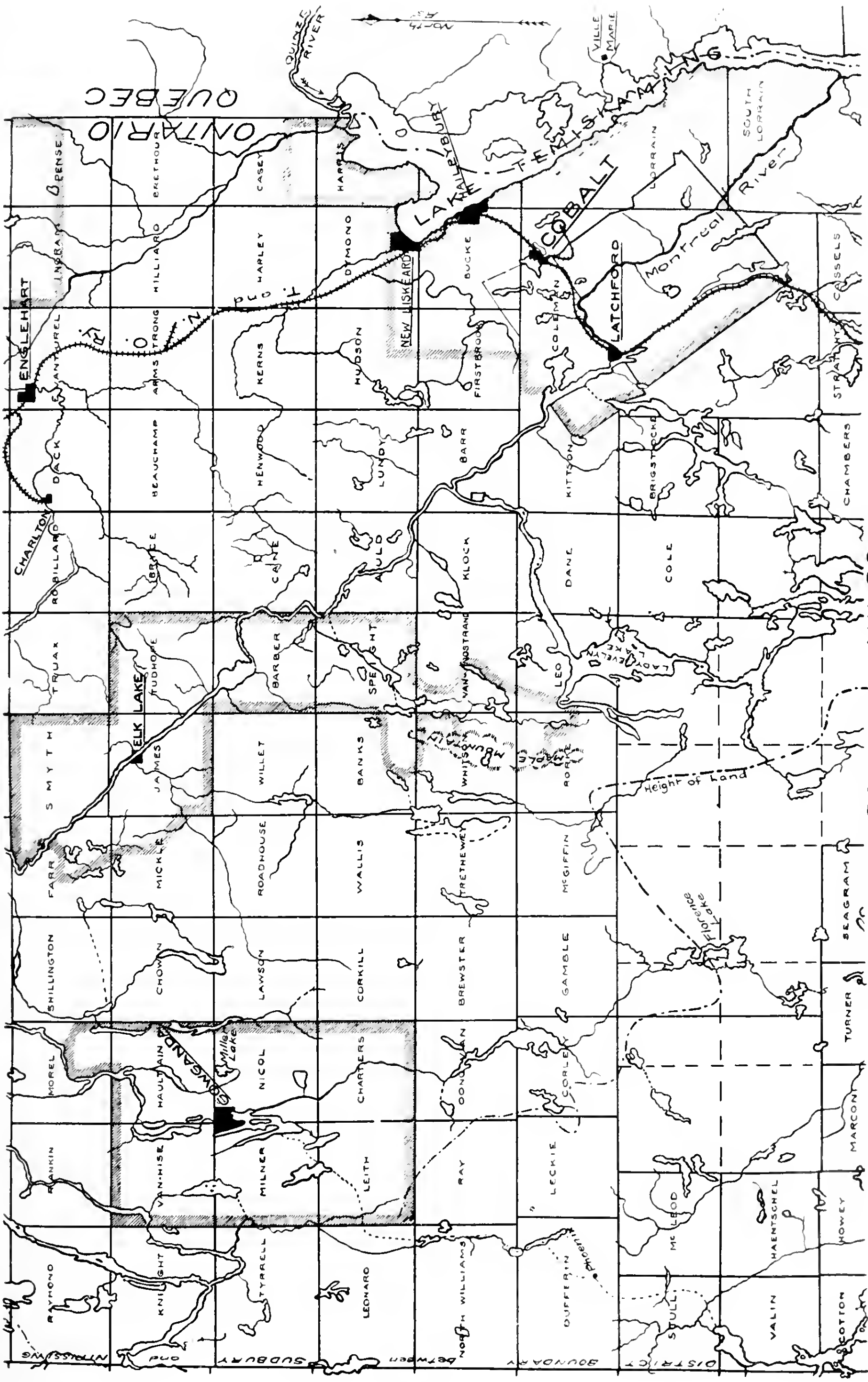

Fig. 57.—Map of Cobalt and outlying silver-cobalt areas. The areas enclosed by hatching have been mapped geologically.

PRE-CAMBRIAN

NIPISSING DIABASE

Igneous Contact

COBALT SERIES

Quartzite, arkose, conglomerate, slate, breccia.

Great Unconformity

LORRAIN GRANITE

Syenite, granite, intrusive into the Keewatin, but not into the Cobalt series.

Igneous Contact

KEEWATIN

An igneous complex, chiefly basic igneous rocks together with acid porphyries.

Fig. 58.—Overlooking Lake Temiskaming from hill south of "666," South Lorrain.

Glacial and Recent

Over considerable of the area there is a covering of drift, carrying the usual glacial boulders. On the summits of the ridges, the drift is sometimes very deep. The rock exposures are usually found along the slopes of the hills, where the drift is thinner. On the shore of lake Temiskaming just south of the townsite, the fine-grained green rocks well preserve the glacial striæ. On the main shore, just opposite a small rocky island, the striæ are very striking, and are due south (magnetic). At other points along the shore, there is a little variation to the east or west of south.

In the cutting of the government road just east of H R 69, the clay shows a stratified arrangement. Clay hills are seen along the shore of the lake, to the mouth of the Montreal river. Five miles up the river, the clay hills are very high and much cut by deep ravines.

The total distribution of the drift is not shown on the map, but only where the working out of the contacts was seriously interfered with.

Nipissing Diabase

This formation has its greatest development in the central portion of the area, where it occurs as a sill, extending westward from lake Temiskaming, around the north end of Loon lake, southwest to the east side of Trout lake, and north almost to the Lorrain boundary. In this area it occurs as a very prominent ridge. A smaller area is seen in the northwest portion, where it is associated with the quartzite. In appearance and texture the diabase is very similar to that described in Dr. Miller's Report on the Cobalt Area, Third Edition, and is essentially a quartz-diabase. A thin section of diabase taken from near the contact with the Keewatin on claim R L 471 shows a distinctly ophitic texture. Laths of plagioclase (labradorite) are embedded in a groundmass of augite, which is partially altered to greenish hornblende. Quartz in micrographic intergrowth with feldspar fills the interstices. A few grains of biotite and magnetite are also present. The feldspar is unusually fresh in the section.

A marked occurrence of the diabase is a dike, about five chains in width and traceable for two miles, intruding the quartzite. This may be seen east of G F 26, and a short distance south of the Lorrain boundary. The dike is very fine-grained on either side, and towards the centre has the normal diabase appearance.

There are smaller patches of diabase in the basic Keewatin areas, and these are difficult to distinguish as to age. Some of them are likely of the same age as the Nipissing diabase, but, owing to the difficulty of separation from the other rocks, are not shown on the map. A thin section of a diabase associated with the Keewatin on R L 468 shows rather fresh plagioclase set in the augite. The latter is greatly altered to green hornblende (uralite). Some grains of quartz are seen in the section.

Along the north line of G F 12 there is a reddish granitic rock, which is apparently of the same age as the diabase, and a separation from the same magma.

Contact with the Cobalt Series

Just north of the Keeley mine road, and west of Loon lake, on G F 13, the intrusive diabase (to the west) overlies the slate of the Cobalt series, at a high angle.

Cobalt Series

The predominating rocks are conglomerates and quartzites. The southern part of the area is composed essentially of conglomerates, varying considerably in appearance. The usual variety is that containing subangular and rounded boulders of granite, syenite and greenstone of varied size, in a groundmass of greenish chloritic material. At the "Notch" of the Montreal river, the rock is a greywacké conglomerate. A peculiar conglomerate is seen about one-half a mile south of Oxbow lake. Here the boulder inclusions are very few, and the surface shows rounded, pea-like inclusions, harder and darker than the surrounding rock. South of Trout lake on H R 163, in a high rounded hill, coarse boulder conglomerate overlies well-banded slate. At the south end of the same lake and to the east, conglomerate and slate overlie the Keewatin, which shows in a bluff.

Rocks near Mouth of Montreal River

The geology near the mouth of the Montreal river and the shore line of lake Temiskaming, north of the river, has been described as follows by Dr. A. E. Barlow:

"At the notch near the mouth, the river flows through an extremely narrow channel with rocky perpendicular walls composed of dark-greenish greywacké slate, much jointed and broken. This gorge has a breadth varying from sixteen to thirty-three feet, and is a little more than a hundred yards long, with perpendicular walls about forty feet high."

"The western shore of lake Temiskaming, from the Montreal river to Roche McLean, is occupied by the massive bedded breccia-conglomerate, which dips in a westerly direction at an angle of 15 degrees.

"In the breccia-conglomerate the matrix is often present in very subordinate quantity. The most abundant fragments are the usual biotite-granite type, while others of a pale granitic rock are seen in thin section under the microscope to consist of phenocrysts of plagioclase or orthoclase, embedded in a fine-grained quartz-feldspar groundmass.

"Besides these there are some fragments composed of a fine-grained altered diabase and others of a greenish-grey slaty rock (resembling in a most marked manner the compact variety of the greywacké of the Huronian) and some grey quartz. The material filling the interspaces is seen under the microscope to consist of a confused aggregate of scales and grains of chlorite and epidote, with abundantly disseminated particles of iron ore and fine granules of sphene and epidote."

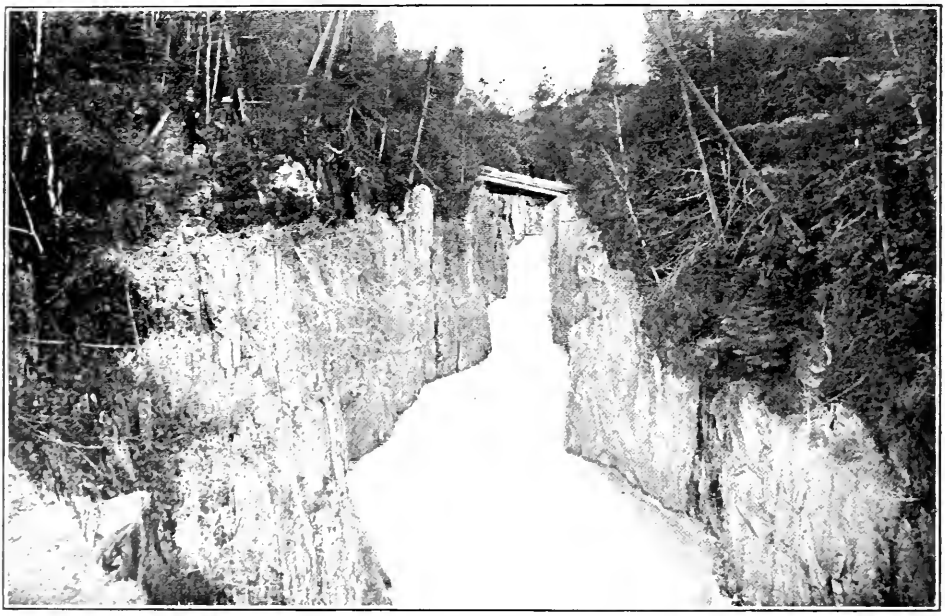

Fig. 59.—The "Notch," near mouth of Montreal river.

"A specimen obtained from an exposure two miles north of the Montreal river, however, showed the matrix to be relatively more abundant than usual. The diabase pebbles are also more plentiful than those of red granite, while fragments of simple minerals predominate greatly over those of composite rocks. The quartz and feldspar fragments are sharply angular, while the composite individuals are as a rule somewhat rounded."*

Greywacke

Just west of the No. 3 post of H R 34 is an outcrop of greywacké which overlies the Keewatin and is overlain to the west by conglomerate.

The greywacké, in thin section, is seen to consist principally of orthoclase, finely twinned plagioclase and calcite, and in subordinate amount, chlorite and quartz. A fragment of greenstone was noticed in the section. This greywacké, which is very deceptive in appearance, was mistaken by prospectors for fine-grained diabase.

*Report on the Geology and Natural Resources of the area included by the Nipissing and Temiskaming map sheets, etc. A. E. Barlow, Tenth Report, Geological Survey, Canada, 1897.

Quartzite and Arkose

The quartzite and arkose have a great development in the north and west portions of the area. They are varied in color and texture, but are usually rather medium-grained, and the lines of stratification are not very noticeable. The prevailing colors are greenish, greyish, and reddish, and, in this area, the green variety is usually rather friable, whereas the red variety is hard and compact. These varieties seem to pass gradually one into the other on the same ridge. The chief constituents are quartz and feldspar, which are occasionally present in large angular fragments. The green color is due to the presence of sericite, an alteration product of feldspar, and was first noticed in the sea-green quartzites along the shore of lake Temiskaming. When the rock is coarse it is difficult to distinguish in the field from granite, particularly when the red feldspar is present.

In this area the prevailing dip of the rocks of the Cobalt series is to the west, varying to the northwest. Near the No. 1 post of L O 144, the slates dip to the west at an angle of 20 degrees. One mile west along the Keeley road from lake Temiskaming, and on H R 30, the slate and quartzite strike northeast and southwest and dip to the northwest. In the northwest portion of the area, near the No. 4 post of T C 77, the slates and quartzites dip to the southeast.

A breccia *in situ* is seen just east of No. 1 post, R S C 68. It is composed entirely of small angular fragments of greenstone, which is seen in place to the south. This is the lowest portion of the Cobalt series seen in this area.

West of the Keewatin area, which is shown to the north of Trout lake, the rocks of the Cobalt series have been laid down in the following order. The Keewatin is usually overlain by a conglomerate, sometimes slaty. Above this, there is a narrow band of reddish banded slate, rather quartzoze toward the upper portion, and overlying the latter there is a large area of quartzites and arkoses, with very little evidence of stratification. The breccia, mentioned above, was only noted at the one point in a very small outcrop.

Lorrain Granite

The Lorrain granite is represented in the northeast portion of the area, by a reddish hornblende syenite, in which flesh-colored feldspar and greenish black hornblende are easily recognized. In thin section, in addition to the orthoclase, there is abundant acid plagioclase and microcline. The hornblende is the common green variety, very pleochroic, and shows the distinctive prismatic cleavage and angles of the amphiboles. Quartz is present in smaller grains than the feldspar, and is not prominent enough for a granite. Sphene and magnetite occur as accessory minerals.

Throughout the syenite are rather rounded patches usually darker in color, but which are composed of the same constituents. These are basic secretions from the original magma, formed during the process of cooling. There are also some very small patches, which are apparently remnants of a conglomerate formerly overlying the syenite.

Where the syenite comes in contact with the Keewatin to the south, it is found to be younger, enclosing fragments of the greenstone, and occasionally intruding, for some distance, the older rock. On L O 153 the syenite is intruded by a very basic trap dike, ten feet wide and striking east and west.

Keewatin

The rocks of this series occur in several isolated areas. They are usually altered basic igneous rocks, both massive and schistose. The largest exposure extends N.N.E. from Trout lake for two miles. These are, in great part, greenish weathering rocks. The most typical portion is fine-grained, with a slaty appearance when fractured. Throughout the fine-grained rock are bands of coarser varieties, now much altered to amphibolite.

Just south of Loon lake, on H R 57, the Keewatin is represented by very coarse massive amphibolites, which are highly mineralized with magnetite and iron pyrites.

Quite different in appearance from those above mentioned are the metamorphosed rocks three-quarters of a mile south of Loon lake, and extending from H R 114 to lake Temiskaming. These are seen as highly tilted bands, with a general strike a little north of east and almost vertical dip to the north. At the west end of this belt the prominent rock is light colored, weathering to an ashy gray. When freshly broken it has almost a cherty appearance and is exceedingly fine-grained. Locally it is much twisted and crumpled. Thin sections of two samples of this rock showed the original character to be entirely destroyed. The constituents are exceedingly fine-grained and secondary, consisting of quartz, feldspar, chlorite and hornblende or mica.

Folded in the bands of this schistose rock are small dikes of light colored porphyries, showing phenocrysts of reddish feldspar.

A thin section from one of these dikes, near the No. 1 post of H R 114, shows phenocrysts of orthoclase and plagioclase, traversed by numerous small veinlets of epidote and hornblende. The groundmass is a granular mixture of feldspar and quartz, with needles of hornblende. Other dikes of porphyry are much fresher in appearance and seem to be younger in age.

On following this belt to the east, the rocks become darker in color and more chloritic. On H R 186 is a typical chlorite schist, striking E.N.E., and dipping to the N.N.W. at a high angle. This rock breaks into curved cleavage plates, and is traversed by numerous small torsion cracks, filled with calcite. On H R 119 and 120 the schist is intruded by a large dike of white weathering porphyry, with colorless phenocrysts of feldspar and quartz.

Small veins of quartz, impregnated with iron pyrites, cut the schist in this vicinity. On H R 140 one of these carries low values in gold.

There is a belt of somewhat similar Keewatin rocks immediately south of Oxbow lake.

Keewatin West of Point Fine

The formation consists principally of rusty, metamorphosed, basic igneous rocks, which may now be classed as amphibolites. In several thin sections, the ferromagnesian mineral is shown to be green secondary hornblende. Just north of No. 1 post of R L 469, the amphibolite is much intersected by veinlets of rusty quartz and iron pyrites. These veinlets stand out very strikingly as a ribbed structure from the dark rock. A thin section of the rock shows it to consist of small rods and patches of green hornblende, partly in parallel arrangement, grains of epidote and clear secondary feldspar. The original character of the rock is obliterated. On H R 74 much of the rock is very fine-grained and intersected by veinlets of epidote and iron pyrites. A thin section shows the rock to be an alteration of a fine-grained diabase, as the ophitic texture is shown clearly in the rods of altered plagioclase. The albite twinning in the feldspar is occasionally seen. The augite has been altered entirely to green hornblende. A coarser grained rock, outcropping near the No. 1 post of R L 465, has resulted from the alteration of a gabbro. The feldspar is now altered to saussuritic minerals, and the pyroxene has changed to a very pleochroic green hornblende, now showing with ragged outline and bent forms. Only occasionally in this belt do the rocks show a schistose structure.

Discoveries

The principal discoveries here have been made near the line of contact of the Nipissing diabase and the Keewatin in the area to the north of Trout lake. Along this contact, usually within a quarter of a mile, discoveries of native silver or smaltite have been made in both formations. The Wettlaufer veins are in the diabase, whereas the Keeley veins are in the Keewatin. Toward the north end of this belt the discoveries so far consist of smaltite and niccolite. Small showings of native silver have

been found in other isolated areas of the Keewatin or diabase. The writer does not know of any discoveries of native silver in the conglomerate or quartzite, although both these rocks are seen in contact with the Nipissing diabase. In this respect the conglomerate of South Lorrain resembles that around Elk lake, in which no native silver discoveries, as far as is known, have been made.

In the following is a description of a few of the promising veins on some of the properties:—

Wettlaufer

On the Wettlaufer claim, H R 85, there were found three parallel veins with a strike N.E. and S.W. Of these, the two northerly veins had rich shoots showing native

Fig. 60.—A vein showing in pit on the Wettlaufer property, South Lorrain, October, 1908.

silver in sheet form, while the south vein carried smaltite with low silver values. The veins were narrow, but parts of them attained a width of six inches. Flake silver is shot into the diabase wall rock from one to three inches. The distance from the north to the south vein is about ninety feet.

The following information on development is taken from Mr. E. T. Corkill's Report on "Mines of Ontario," in 21st Annual Report Bureau of Mines, 1912.

"The Wettlaufer is the largest and the only steady producer in South Lorrain. It is owned and operated by the Wettlaufer Lorrain Silver Mines, Limited, which have an authorized capital of 1,500,000 shares, of a par value of $1.00, and have paid $450,000 in dividends to June 1st, 1912.

"On the advent of electric power to the camp from the British Canadian Power Company, a new plant was installed, consisting of a 12-drill compressor, driven by a 200-h.p. motor. A 30-ton concentrating mill has been erected.

"The main shaft has been sunk to the fourth level, a depth of 250 feet. Levels have been run at depths of 65 feet, 140 feet, 185 feet and 250 feet. The vein has been developed for a length of about 500 feet, the drifts on each level having been run approximately this distance. A winze was sunk at a point 210 feet southwest of the shaft from the fourth to the fifth level, and a drift run south 160 feet and north 70 feet.

"The winze has since been sunk to the sixth level.

Bellellen

"On claim R L 470 the Bellellen Silver Mines, Limited, have carried on considerable development work. No. 1 shaft is 80 feet deep, with 144 feet and 114 feet of drifting north and south of the shaft on the 80-foot level; some stoping has been done. No. 2 shaft is 100 feet deep, with 200 feet of drifting and cross-cutting at the 100-foot level.

"The plant consists of a 20-h.p. boiler and hoist.

King George

"Active development work was carried on during 1911 on claims H R 110 and 170. The main shaft has been sunk a depth of 272 feet, with 30 feet of cross-cutting at the 250-foot level.

"The power plant consists of a 5-drill compressor, driven by a 75-h.p. motor, and a hoist. Electric power is obtained from the British Canadian Power Company.

Montrose

"Work on R L 459 was carried on part of the year by the Montrose Cobalt Mining Company. A shaft was sunk a depth of 110 feet.

Sharp Lake

"On claim B C 100 the Sharp Lake Mines, Limited, have sunk a shaft a depth of 50 feet. At the 50-foot level a drift has been run south 145 feet and east 60 feet."

Keeley

At the Keeley mine, H R 19, considerable development has been done. At the shaft on the main vein, No. 1, the strike is S. 62° E. The silver occurs in wire form, flake-like sheets and hair-like tufts, associated with smaltite in a gangue of quartz and calcite. Quartz is very prominent in the vein, and is associated with the best values.

The main shaft on the original discovery has been sunk to a depth of 150 feet. At the 65-foot level, 300 feet of drifting has been done on the vein, and about 60 tons of shipping ore have been taken out and bagged. The shaft is in the Keewatin formation. Dikes of old diabase have been encountered. At a depth of 130 feet crosscuts have been driven 75 feet east and west respectively. Associated with the ore is more or less cobaltite. A sulphide of copper and silver, probably stromeyerite, has been found in the No. 1 vein. Shaft No. 3, about 600 feet south of No. 1, is 70 feet in depth.

A sample of massive ore from a vein near the west side line of this property, analyzed by Mr. N. L. Turner, Provincial Assayer, shows it to be smaltite-chloanthite, with the following composition:

Cobalt	10.00%
Nickel	8.16%
Arsenic	68.72%
Sulphur	.42%
Silver	8.7 oz. per ton

Jowsey-Woods

On H R 21 there are several calcite veins and one of them has shown on development native silver. This vein is near the east side line and strikes about N.N.E. A shaft has been sunk to a depth of 110 feet, and on the 75-foot level 75 feet of drifting has been done. The gangue is calcite, which has a very fine cryptocrystalline texture, associated in bands with quartz and decomposed material. Leaf silver, in small flakes, has been found in the vein, associated with smaltite, copper pyrites and native bismuth. Minute crystals of chloanthite are scattered through the gangue.

On H R 16 (Haileybury Silver Mining Company) the original discoveries were smaltite and niccolite. A sample of the massive ore has the following composition:

Cobalt	15.92%
Nickel	11.18%
Arsenic	60.38%
Silver	trace.

The vein has a strike of S. 20° E., and dips 70° to the east.

On this vein a shaft has been sunk to a depth of 100 feet, and about 15 tons of massive smaltite have been obtained. Twenty-five feet of drifting have been done at this level. The chief vein filling is calcite and decomposed material.

Later a vein showing native silver was discovered on the south half of the claim.

Frontier

The south half of H R 16 was sold to the Haileybury Frontier Mining Company. A shaft has been sunk on the vein to a depth of 90 feet. At this level drifting was carried 60 feet to the northeast and 125 feet to the southwest. No. 2 shaft, about 500 feet southwest of No. 1, is 110 feet deep, with some crosscutting. The veins on this property are in the Keewatin.

On H S 42 (Forneri claim) there is a vein about 3 inches in width, with strike N. N. E., and occurring in the conglomerate. The vein material is smaltite and copper pyrites in calcite and quartz. A surface sample on assay showed no silver values. A shaft has been sunk to a depth of 75 feet. At 35 feet the vein dipped from the shaft. It is reported that silver values were obtained on assay at 14 feet depth.

On R L 471, near the east side line, there is a strong vein of massive smaltite, on which a shaft has been sunk 65 feet. The vein is in the Keewatin.

On H R 106, adjoining Trout lake on the northeast, a five by seven shaft has been sunk 50 feet on a calcite vein carrying smaltite.

On T C 73 there is a shaft down 40 feet on a calcite vein with disseminated smaltite and copper pyrites. These veins have not proved to carry appreciable silver values. The rock is the Nipissing diabase.

On H R 69 (Maiden claim) there has been extensive development work. Near the east side line, a tunnel has been driven from the base of a hill a distance of 285 feet on a calcite vein. At 100 feet a winze has been sunk to a depth of 60 feet. The vein in places has a width of 12 inches. Smaltite and niccolite are found in bunches in the vein. Low silver values are reported to have been obtained on assay. On vein No. 2 to the west a tunnel has been driven 225 feet. The vein filling is chiefly calcite with smaltite and niccolite in portions of the vein, 5 to 7 inches in width. The veins are in the Keewatin just north of the contact with the Nipissing diabase, and strike a little east of north.

On H R 14, near the west side line, some native silver has been obtained in a narrow vein in the diabase.

On T C 71, east of Loon lake, a tunnel has been driven 100 feet on a strong calcite vein about a foot in width.

At other parts of this area there has been considerable prospecting, consisting of trenching and sinking of small pits and shafts. Calcite veins are the most common type, the calcite being usually associated with more or less quartz, and carrying smaltite and

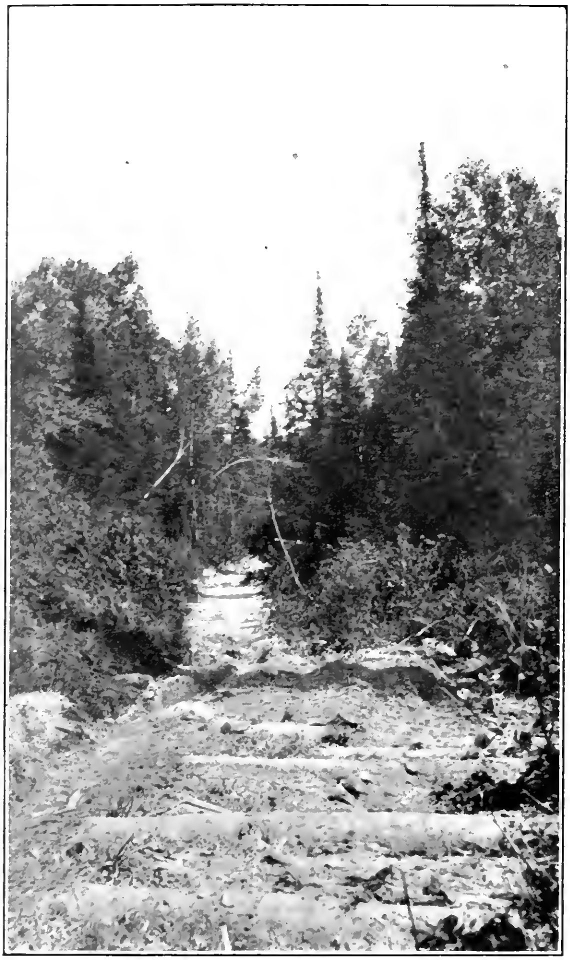

Fig. 61.—Old timber road, South Lorrain.

niccolite occasionally. These latter minerals have been found on a number of claims in well-defined veins.

Aplite dikes which are characteristic of many of the silver showings in the township of James and vicinity are of little importance in South Lorrain.

TOWNSHIPS OF CASEY AND HARRIS

By R. E. Hore

On August 14, 1906, with Mr. Gerald Galt, I went west from the Blanche river along the Casey-Harris township boundary to lot 5, Casey township. From our camp at this point we examined the country for about three miles around.*

Casey Cobalt

About one hundred yards west of the southeast corner of lot 5, concession 1, Casey township, cobalt bloom was discovered by David Bucknell. Mr. Bucknell having seen the silver veins in conglomerate rock at Cobalt, recalled an outcrop of similar rock on a neighbor's farm, returned home, and found a vein the same afternoon.

A shaft sunk on the vein disclosed an ore body which is in some parts five inches in width. The chief values are in cobalt, nickel and arsenic, which are present in the minerals smaltite, chloanthite and niccolite, in calcite gangue. No silver was seen in the ore. Partings in the slaty wall rock are frequently filled with sheets of native bismuth for a few inches from the vein.

The vein, where it outcrops at the foot of a conglomerate ridge strikes about 25 degrees north of east. A few feet east of the shaft it disappears under the drift. In the opposite direction it is not well defined, there being only a narrow crevice to indicate its extension up the hill to the west.

A similar, but smaller, vein was discovered during the summer, and it is said to contain some native silver. This vein is about fifty yards west of the first one, which strikes N. 70 degrees W.

Other Claims

Most of the surrounding country is heavily drift covered. Northwards the next outcrop of any extent is in the second concession. About one-half mile to the east a diabase ridge runs northwards. To the west is a low, flat, clay-covered area, which extends southwards to Sutton bay. To the south, however, a ridge of conglomerate, locally called Casey mountain, extends to Sutton creek, and thence eastward along the bay shore.

On the Murray claim, which adjoins the Casey Cobalt, there is a good showing of cobalt bloom. Elsewhere along the outcrop we did not see any important discoveries.

Development Work

At the time of our visit no work was being done on the Casey Cobalt and Murray properties, as negotiations for sale were under way. We could not make a closer examination of the Casey Cobalt vein as the shaft was nearly filled with water. This shaft was said to be only thirty-five feet deep, and consequently little is yet known of the extent of the ore body.

On several of the other properties pits have been sunk on small veins, without remarkable success. The rock has been well exposed in many places by forest fires, thus giving an opportunity for the prospector to work over the district rapidly. Most of the district is, however, heavily covered, and prospecting in the future must be slow and expensive.

Geology

There is a considerable variety in the rocks exposed in this small area. Greenstone, conglomerate and slate, basic and acid igneous intrusions, limestone and clay deposits are all found here.

*The area mapped by Mr. Hore is now included in the fourth edition of the Cobalt map, scale 1 mile to an inch. Mr. Hore's description of the area appeared in the third edition of the report. It has been revised and brought up to date by Mr. Knight. The area is now an important producer of silver. W. G. M.

The greenstone is much metamorphosed and is probably the oldest rock in the district and of Keewatin age. A hornblende syenite of reddish color, intruding Keewatin, may represent the Lorrain granite, on which was deposited the Cobalt series. Diabase intrudes the cobalt series. The limestone must have been deposited after a great lapse of time, as it has been determined to be of Niagara age.

Classification According to Age

	7. Post-Glacial..................Clay.
	6. Glacial........................Boulder clay, etc.
	5. Niagara.......................Limestone.
	Unconformity.
Pre-Cambrian	4. Nipissing diabase.
	Igneous contact.
	3. Cobalt series.................. Conglomerate, arkose, greywacké.
	Unconformity.
	2. Laurentian (Lorrain Granite)..Syenite.
	Igneous contact.
	1. Keewatin.....................Greenstone.

Post-Glacial

A high percentage of this area, and of the district to the north and northwest, is overlain by a deposit of clay and clayey marl. An extensive belt of clay is found on either side of the Blanche river for several miles from its mouth. The river brings down annually a large quantity of similar material, which is deposited in the shallow waters at the head of lake Temiskaming.

Settlers are gradually getting these lands cleared, and find the soil is fairly well adapted for farming purposes.

Glacial

There is very little glacial drift in the area. The only occurrence of any extent is a moraine on the east of, and running parallel to, the Blanche river near Judge P.O.

Niagara

The Niagara limestone of Wabi point covers the western part of the townships of Casey and Harris. The rock outcrops here and there along a cliff, the level of the limestone being over fifty feet above that of the clay flats. Grey colored limestone, interbedded with shales, is the chief constituent of these sediments, which were years ago correlated with the Niagara of southern Ontario.*

Nipissing Diabase

This rock outcrops about one-half mile east of the Casey Cobalt discovery. The immediate contact with the sedimentary rocks is generally covered, and the delimitation of rock areas as shown on the map is therefore only approximate. In field appearance and in mineralogical composition, the several outcrops are quite similar to the diabase in localities to the north and south, where the field relations can be studied. It is therefore considered as part of the same magma as the sills of Cobalt and Wendigo districts.

A typical specimen is a dark gray, medium-grained, crystalline rock, composed of bronze colored augite and light colored feldspars. Nearly all the minerals are colorless in thin section. Under the microscope the large augite individuals are seen to enclose the lath-shaped crystals of feldspar. In subordinate amount are brown pleochroic biotite, green chlorite, and opaque iron ore,—ilmenite or magnetite. The typical diabasic structure is not generally detected by the naked eye, but, except in the coarser parts, is generally seen under the microscope.

*G. S. C., 1863.

The most extensive outcrops are in the southern parts of lots 7 and 8, concession 1, Casey, and in lot 6, concession 2, of Casey.

Cobalt Series

The Cobalt series is made up of greywacké slate, arkose and conglomerate.

Under the microscope the fine grained rock is seen to be composed largely of minute grains of quartz and feldspar, with here and there groups of larger particles of these minerals (körnige grauwacké). Chlorite is a common constituent of the rock, giving it a dark color.

Similar material to this, enclosing pebbles of syenite, granite, diorite, etc., makes up the greywacké conglomerate.

Underlying the conglomerate north of Sutton bay is a rather poorly defined layer of arkose. This consists of medium sized grains of quartz and feldspar and some chlorite.

This series of rocks is remarkably free from any evidence of great disturbance after deposition, and in general character is quite similar to the Cobalt series at Cobalt.

Besides the well exposed ridge, already mentioned and known as Casey mountain, there is an outcrop of considerable extent on lot 5, concession 2, Casey township. Small outcrops were found in lot 6, in concession 6, Harris, and concession 1, Casey.

Laurentian Syenite

Reddish colored syenite outcrops on lots 4 and 5, concession 2, Casey township. A somewhat conglomeratic appearance is given to the rock by the inclusion of fragments of greenstone, which it has picked up in forcing its way through the Keewatin series.

The most abundant mineral in the rock is orthoclase, which is quite reddish in color. Long slender crystals of dark green color, resembling actinolite, constitute the other chief constituent. Under the microscope these green crystals are found to be quite pleochroic, and many cross sections show the typical cleavage and crystal habit of hornblende. Small particles of quartz are found in nearly all specimens, but, as the quantity is quite subordinate to that of feldspar, the rock is nearer the syenite than the granite type. Other minerals are sphene, iron ores and some secondary chlorite. The petrographical character, and the lack of evidence of metamorphism and chemical alteration, shows that the syenite is later in age than the Keewatin. The field relations show that it is older than the Cobalt series.

The syenite here called Laurentian is probably of the same age as the Lorrain granite.

Contact of Laurentian and Cobalt Series

The contact of syenite and conglomerate is very well exposed for several yards. The conglomerate has evidently been formed by sedimentary deposits derived from the syenite and older rocks. At the immediate contact large angular blocks of syenite are cemented together by fine, gray material, forming a breccia conglomerate. A few feet from the syenite the fragments are well rounded, and farther on pebbles of other composition form a greater and greater percentage of the conglomerate, which then appears quite similar to the Cobalt series at Cobalt. Detailed examination may show that the former conglomerate is of later age than the latter; but from our rather hurried survey it seems that they are of the same character and probably deposited at the same time. The conclusion which we come to is, therefore, that the conglomerate is younger than the syenite.

Keewatin

A chloritic igneous rock of basic composition, containing irregular stringers of quartz, is exposed on lot 7, concession V, Harris township. In the field its green appearance distinguishes it from the later diabase.

A typical specimen is a dark colored fine grained crystalline rock, showing small crystals of light colored feldspar. Under the microscope it is seen to consist largely of grains of augite and small feldspar laths. That there has been considerable chemical

alteration is shown by the abundance of chlorite, which results from the decomposition of the augite. That the rock has suffered severe metamorphism is shown by the granulation of the augite individuals, and by wavy extinction in the feldspar crystals.

This outcrop is, therefore, probably an old hill top of Keewatin age, none of the later rocks in the vicinity being much metamorphosed.

Recent Development at Casey Cobalt

Since the above notes were written by Mr. Hore, now several years ago, much work has been done on the Casey-Cobalt, and it has recently become an important shipper. Mr. E. T. Corkill, chief inspector of mines, gives the following notes in the twenty-first report of the Bureau of Mines:—

"This property, situated on the southeast quarter of the south half of lot 5, in the first concession of Casey, about 10 miles northeast of the town of New Liskeard, is controlled by the Casey Cobalt Silver Mining Company, Limited, with an authorized capital of $100,000.

" The power plant consists of two 40-h.p. boilers, a straight line compressor and hoist. A larger power plant is now being installed.

" The shaft has been sunk on the vein, which dips to the southeast at an angle of 70 degrees, to the depth of 260 feet, with levels at 33 feet, 100 feet, 160 feet, 210 feet and 260 feet. Work done during the year was confined mainly to the 210-foot and 260-foot levels. On the 210-foot level, drifts were run northeast 60 feet, and southwest 100 feet. Just north of the shaft is a cross-cut 190 feet in length, and from the drift southeast of the shaft a cross-cut west 140 feet, where a new vein was encountered. On this vein 185 feet of drifting has been done, and a new shaft started. On the 260-foot level, a cross-cut was driven west 100 feet, and 225 feet of drifting done on the vein. A raise was also put through to the 210-foot level. Several car-loads of low-grade ore were shipped to the Northern Customs Concentrator at Cobalt for treatment."

In February, 1912, the mine was visited by C. W. Knight, who found that the shaft passed through 245 feet of conglomerate, greywacké and greywacké slate of the Cobalt series, after which it met with an older complex, consisting largely of igneous rocks, including lamprophyre and fine-grained greenstone; graphite schist was also encountered. In the Cobalt series a minor fault occurs in the lower levels, which has faulted one of the veins about seven feet.

In May, 1913, the property was visited by Messrs. Burrows and Knight. About a quarter of a mile northerly from the shaft of the Casey Cobalt the Nipissing diabase was seen resting on the sediments of the Cobalt series and dipping, apparently, gently to the east. It is probable that the diabase sill originally covered all the rocks on the present hill, it having now been largely eroded. At the Casey Cobalt there is a thickness of 300 feet or more of the Cobalt series. Conditions here are, therefore, similar to those at Cobalt where the greater part of the silver ore mined has been derived from veins in the Cobalt series beneath the Nipissing diabase sill.

AREA SOUTH OF LAKE WENDIGO

By R. E. Hore

On September 3, 1906, with Mr. Gerald Galt, I went to Tomstown to examine an area including parts of the townships of Ingram and Pense and unsurveyed territory northwards to Wendigo lake. In this area there have been several discoveries of small veins which show cobalt bloom in a quartz gangue. A few of them show massive smaltite. No native silver or argentite has yet been discovered. Small quantities of sphalerite and galena have been found in some of the veins.

The discoveries of bloom, which are widespread over this area, are in diabase and gabbro. None were seen in the clastic rocks in the area mapped.

The map which accompanies this Report shows the distribution of the rocks in the area examined by us.

Character of the Country

The southern part of the area mapped is heavily covered, and includes many acres of swamp and muskeg. In the northern part of the surveyed townships, and in the unsurveyed territory, the country is more rugged. The rock is well exposed in numerous ridges, and around the shores of Wendigo lake.

Geology

The lower levels, at the lake shores and south of lake Wendigo, represent a horizon of greywacké slate. Hills of fragmental rock in this area, rising one hundred to two hundred feet above lake Wendigo, show slate, arkose and coarse conglomerate in ascending order. From the south a great sill of diabase and gabbro, rising very slowly, overlying the greywacké slate, extends northwards, touching lake Wendigo at Wilson's bay.

Classification

Nipissing diabase.
Cobalt series............................Conglomerate, arkose, slate.
Keewatin...............................Greenstones.

Nipissing Diabase and Gabbro

The nature of the diabase sill is well shown in a number of places. At the foot of cliffs of diabase, the igneous rock is seen to overlie horizontally bedded, slaty greywacké. At the west end of lake Wendigo the slate dips slightly to the south under diabase. This sill structure is seen wherever the contact is exposed. The cooling of the igneous sheet has produced vertical cylindrical columns. These are often well defined in the ridges north of Ingram township, where columns twenty to thirty feet in diameter form the vertical cliffs, while wide cracks mark out the continuation of the column boundary.

To the naked eye the ophitic structure is not often apparent; but under the microscope most of the finer grained specimens were found to have typical diabasic structure. The coarser parts, as in and north of Pense township, do not show this structure. The fine-grained rock on the west shore of Mallard lake is also gabbro.

A typical diabase is that at the outlet of Wendigo lake. This is a dark grey rock showing light colored feldspar and brown augite. Under the microscope the large individuals of augite are seen to enclose lath-shaped feldspar crystals. There are present a few crystals of magnetite and ilmenite and some brown biotite.

A specimen taken from the east shore near the head of lake Wendigo, is coarser in texture. The augite is partially altered to chlorite. There is more ilmenite and also some quartz and pyrite.

At the narrows about two miles from the foot of lake Wendigo there is a pink colored phase of the diabase. This color is due to an abundance of pink feldspar. The

feldspar and augite are both much decomposed, and chlorite and calcite are prominent secondary minerals. Ilmenite, accompanied by the alteration product, leucoxene, is common. A more acid phase of this rock is composed chiefly of orthoclase, with a few crystals of plagioclase and quartz. The pyroxene has a faint violet color, and is probably titaniferous. It decomposes to calcite and chlorite.

The coarser parts of the igneous rock, such as occur on lot 6, in the sixth concession of Pense township, and north of Pense, contain considerable quartz. The quartz is often in graphic intergrowth with pink colored feldspar.

A fine-grained type, on the Le Roy claim, Mallard lake, is composed largely of yellowish-brown pyroxene along with a small proportion of plagioclase feldspar. Chlorite has resulted from alteration of the pyroxene. Magnetite and ilmenite are also present.

Isolated outcrops on the Blanche river, in the neighboring townships of Marter and Evanturel, have been described by W. G. Miller* and W. A. Parks.†

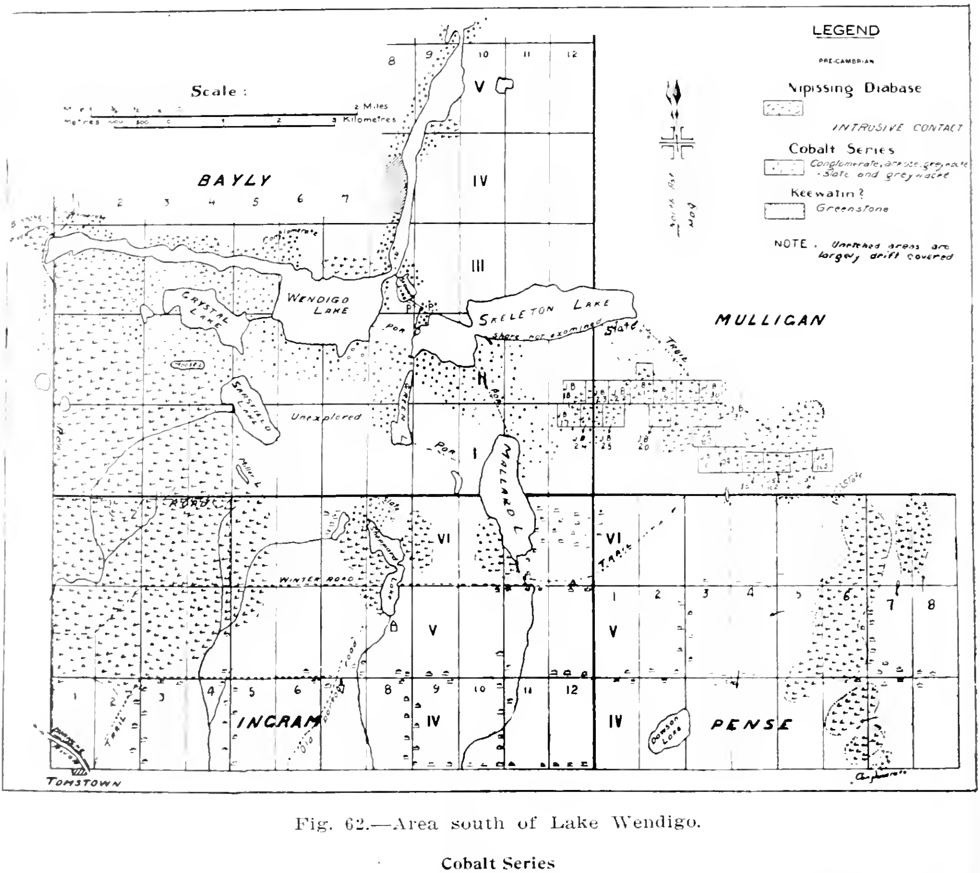

Fig. 62.—Area south of Lake Wendigo.

Cobalt Series

The clastic series may be conveniently divided into three parts: greywacké, arkose and coarse conglomerate. The change from one to another of these is generally by insensible gradations; but in good exposures in cliffs it is possible to define the layers approximately. The order is the same as at the Little Silver Cliff at Cobalt, greywacké slate being the lowest member and conglomerate capping the ridges.

Under the microscope these rocks are found to be quite similar to those of Casey township described in this Report.

*L. Temiskaming to the Height of Land, Annual Report Bureau of Mines, 1902, p. 228.
†From L. Temiskaming Northwards. Summary Report, G. S. C., 1904, p. 214.

A good exposure showing these rocks is in the cliff at the north of Green lake. The arkose layer, here as elsewhere, is only a few feet in thickness. Below the arkose, greywacké is exposed for fifty feet. Above, is a somewhat thicker bed of coarse conglomerate.

There is a rather large area of arkose south of the foot of lake Wendigo. It is a light colored rock composed of quartz and feldspar cut by numerous small stringers of quartz. Some darker phases of the arkose receive their color from chlorite. Similar rock outcrops southeast of Beaver lake.

Underlying the gabbro in the southeast corner of lot 6 in the fifth concession of Pense there are several alternate layers of greywacké and arkose varying in thickness from 4 inches to 3 feet. The greywacké is composed of very small particles which are scarcely distinguishable. The arkose contains a high percentage of chlorite, and is consequently quite dark in color.

Keewatin

On the west shore of the north arm of lake Wendigo there is a series of greenstones which are probably of Keewatin age. These consist largely of pyroxene rocks which have suffered considerable granulation and chemical alteration. A porphyritic phase contains crystals of orthoclase, augite and hornblende in a fine-grained ground mass of the same materials.

As we did not examine the territory north of lake Wendigo, the field relationships of these rocks are not known. From the petrographic characters alone, it seems most likely that they belong to the Keewatin series.

It is noteworthy that in the area mapped south of lake Wendigo, the diabase sheet does not come in contact with rocks of Keewatin age, and in this respect the geology differs from that at Cobalt.

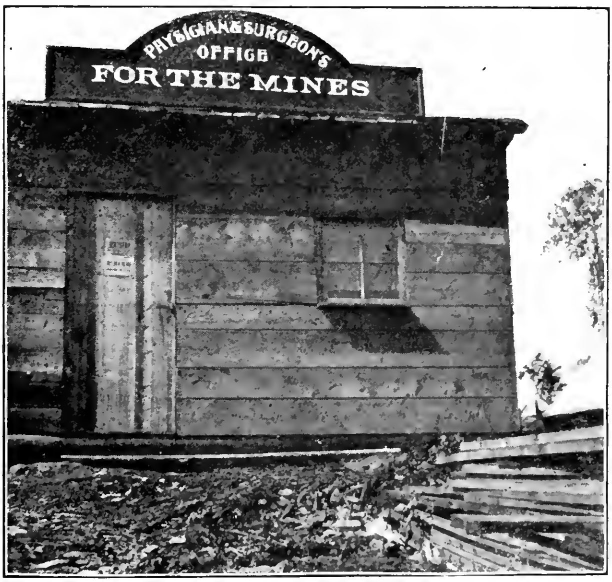

Fig. 62a.—Physician's office, Cobalt, July, 1905.

THE AREA WEST OF BAY LAKE ON THE MONTREAL RIVER

By J. S. DeLury

Introduction

On July 16th, 1906, acting on instructions from Professor Miller, the Provincial Geologist, the writer proceeded from the Government camp, on Giroux lake near Cobalt, to the west side of Bay lake to map out the geological features, and to examine the mineral claims which are staked out there. The area was mapped by Dr. Barlow, of the Dominion Geological Survey, and was included in his Temiskaming and Nipissing map sheets issued in 1899. This map and a blue print made by the Ontario Crown Lands Department from timber and mineral lands surveys, were used as a basis for the topography. In mapping in the geological features, owing to the very limited time in the field at the disposal of the writer (namely, from July 17th to July 31st), distances were paced from exactly surveyed lines such as timber and mineral claim lines; angles were measured with a prismatic compass.*

The area mapped embraces the country bounded on the north and east by Bay lake and the Montreal river, and on the south and west by the Gillies and Booth timber lines (now the western boundary of Coleman township). The country covered by the writer is fairly well wooded, though the best timber has been removed by the lumberman. A good wagon-road runs from the mouth of Trout creek to an old lumber camp on the east end of Trout lake; there are also roads cut out from Trout creek, near its mouth, to several of the mining claims to the south. A portage trail runs westward from about the middle of Bay lake to the extreme eastern end of Anima-Nipissing lake; this, according to Dr. Barlow, was cut out under the directions of Father Paradis, in 1891, to form a winter road from Bay lake to Temagami. Trout creek is the only navigable stream in the area mapped, and only small boats can go up this for a short distance from its mouth.

Glaciation has left its characteristic topography, the country consisting of small valleys and hills which show glacial striations.

Rocks of the Area

The only sediments occurring here are banded slates and quartzites, together with some intermediate rocks. These seem to belong to the Cobalt series, and are a continuation westward of the same rocks mapped by Professor Miller in the Cobalt area, east of Bay lake. In every place where both types of rock could be seen together, they were quite conformable, there being a regular transition from banded slates below to typical white quartzite above; this transition zone, usually of considerable thickness, and made up of rocks intermediate between the slates and quartzites, shows that the banding of the slates is parallel to the bedding of the lower quartzites; these lower bedded quartzites, which are quite impure, pass into white quartzites, and these, on account of their lack of impurities and constant composition, show no bedding planes. These rocks were doubtless deposited as a result of water action over wide areas. None of the old Keewatin formation was positively identified in this section of the country, though on the northwest side of Trout lake, outside of the area mapped, was an exposure of what seemed to be an old Keewatin greenstone.

The only igneous rocks of the area are diabase and gabbro intrusives, which cut the slates and quartzites above mentioned. These rocks come up in the form of narrow dikes, which seem to be near the vertical in position, and in no case has an extensive metamorphism of the sedimentaries resulted from their intrusion. The larger diabase and gabbro dikes have altered a narrow zone of quartzite along the contact; and in many cases small zones (usually less than two yards in width) of autoclastic rocks or friction breccia were formed. In one place in particular (on J S 54) a zone, from two to three yards in width, consisting of compressed fragments of diabase and quartzite, lies between

*The area mapped by Mr. De Lury is now included in the fourth edition of the Cobalt map, scale 1 mile to an inch.

the unaltered intrusive and the typical unaltered quartzite. Along most of the contacts, however, the quartzite has been crumbled for a short distance from the contact, and these fragments having been compressed and cemented together, form a coarser-looking quartzite, which in some cases looks like an igneous rock. This is particularly the case when the quartzite is rather impure. In no place was a contact observed between the slate and the intrusive, so that the metamorphic effects on that rock could not be observed. This is probably owing to the fact that the slate, having been more readily glaciated than the diabase and quartzite, is generally flat and drift covered.

The diabase and gabbro resisted glaciation more than the sedimentaries, and throughout the area stand out in relief from the quartzite as well as from the slates.

The individual rocks will now be briefly described:

Banded Slate

The slates are of the type described by Dr. Barlow and Professor Miller for similar areas in the Temiskaming district; they are of the so-called banded type, showing fine banding of alternating greenish, reddish and dark bands. This pronounced banding indicating the bedding, and higher up the general conformable transition into slaty-bedded quartzites leave no doubt as to the true sedimentary nature of the slate, and indicate that the slates have been deposited as a result of water erosion and deposition over wide areas. Except where they approach the quartzites, they are very fine and even grained, and in no case noticed did they contain any larger fragments of clastic material. The darker and greenish colors are probably due to secondary silicates such as chlorite and the reddish stain of some of the bands is likely caused by the presence of hydrated iron oxide. As the quartzite is approached above, the slate changes into chocolate-colored, fine to medium grained, intermediate rock, which is in most places of considerable thickness.

Quartzite

With the gradual transition from the banded slates below through an intermediate zone of quartzitic slates and slaty-quartzites, the impure quartzite comes in above, and higher up the typical white quartzite. As there is no superior formation the thickness of this quartzite bed could not be ascertained. No quartzite was found consisting of pure quartz though the higher quartzite has a greater percentage of free silica. In all the quartzite is a considerable amount of feldspar and most of it shows small amounts of white mica. As the slate is approached below, the impurities increase, the coloring matter, such as iron oxide and secondary silicates become more prominent and the quartzite becomes gradually darker in color.

A thin section of the whitest quartzite examined under the miscroscope shows the following: The rock is made up of even, rounded grains, the major part being quartz; orthoclase and microcline are in a considerable amount and a little plagioclase can also be seen. This section shows no mica though in many fragments it may be seen without the assistance of a microscope. The quartzite is evidently formed from sandstone by great pressure and some cementation, as some of the quartz fragments show additional secondary silica.

Nipissing Diabase and Gabbro

The exact age of the intrusives could not be ascertained, though from their general appearance and degree of alteration, it is probable that they are the result of the same active period that caused the similar intrusions in the Cobalt area.

The smaller dikes of intrusive rocks are typical diabases, very fine-grained near the contact, and becoming more coarsely grained and more acid as the centre is approached. In the centre of the larger intrusives the rock is more of the gabbro type, being coarser grained and more granitoid in structure than are the edges of the same intrusive and the smaller dike rocks. The diabase and gabbro have undergone some alteration, particularly near the surface; diabase from some of the shafts was quite fresh looking and resembled very closely the diabase of the Cobalt area.

Several thin sections, prepared from fragments taken from the dikes at different distances from the contact, were examined under a microscope. Near the contact the

diabase is fine-grained and considerably altered; the plagioclase is much kaolinized and the ferro-magnesian minerals are almost entirely changed to secondary chlorite and serpentine. Ilmenite, changing into secondary leucoxene, is quite a prominent constituent. As the contact is left, free quartz is noticeable in the section, and at the centre of the larger instrusives a micrographic intergrowth of quartz and orthoclase is quite pronounced. This last probably represents the part of the original magma which was last to cool.

An interesting exposure of porphyritic diabase can be seen on the timber line between V lake and Trout lake. This consists of a typical diabase in which are embedded large phenocrysts of plagioclase some of which are about three inches in length. The exposure is so small that it is mapped as part of the ordinary diabase-gabbro intrusion.

Veins and Mineral Indications

At the time the claims were visited, no great depth had been attained in prospecting; the shafts were sunk on only about five claims, namely, J S 53, J B 33, J B 29, J B 32, and J S 50.

The veins of the area are made up principally of calcite gangue, and near the surface there is cobalt bloom, pyrite, and chalcopyrite. Deeper down in the veins, where shafts have been sunk, occur small quantities of smaltite, and sometimes niccolite. The veins are very irregular and are either altogether in diabase or are on the diabase contacts. Some of the veins, particularly those associated with the smaller dikes, follow through the diabase within a few feet of the contact. In the larger intrusives the veins are most irregular, and run through the diabase with no definite strike or dip. The veins along the small diabase dike near the mouth of Trout Creek, are examples of the former type; in fact, there seems to be a fractured zone following the whole length of the west contact of this dike. The small area of diabase near where the Montreal river widens into Bay lake contains a small stringer of calcite showing chalcopyrite. Of the deposits in the larger bodies of diabase-gabbro, the most important are in J B 33 and J S 53. On J B 53 (the Edison claim) is a network of calcite stringers, some of which approach a foot in width in the larger parts. Cobalt bloom is found at the surface and, deeper down, smaltite is found, though not in paying quantities at the time the property was visited.

In the cases where shafts have been sunk the mineralization seems to increase with depth. In no cases were silver minerals noticed, though low silver assays were claimed on two of the properties. Most of the claims, particularly those not in the diabase, had no lines to their discoveries. As many of these are located on quartzite and as no good indications were observed at any place in that rock it is probable that nothing of importance will develop on these properties.

Unlike the slate-conglomerate near Cobalt, the quartzite does not seem to be fissured. A small fissure in diabase about one mile due north of the extreme east end of Anima-Nipissing lake contains small quantities of stibnite.

The Claims on Whitewater Lake

Three days were spent on a trip through Anima-Nipissing lake to Whitewater lake in the Temagami Forest Reserve to examine certain mineral claims which were staked out there. On the eastern side of the middle enlargement of Anima-Nipissing is a pyrrhotite deposit associated with what seems to be granite rock. It was claimed by the owners that it contained a small percentage of nickel. An exact idea of the importance of the deposit could not be obtained at the time of this examination.

On the claims near Whitewater lake, nothing very valuable was seen, though none of the veins had been developed. Claim T R 2 showed a quartz stringer in diabase holding some chalcopyrite and showing secondary copper stains. T R 6 was the only claim bearing indications of cobalt. There was a little bloom associated with calcite in a small crack in diabase. The other claims examined showed nothing of importance and few of them had lines to their discoveries.

MONTREAL RIVER AND TEMAGAMI FOREST RESERVE

Including Townships of James, Tudhope and Others

By Cyril W. Knight

The third edition of the report was accompanied by a geologically colored map, which included thirty townships, of which the township of James is distant 37 miles northwest of Cobalt. This map is now out of print, but the present edition of the report is accompanied by two black and white maps, Figs. 57, 63, which include the more important areas shown on the colored map.

While much of the surface of the country is similar to that at Cobalt, the southwest part in the vicinity of Anvil lake, includes some comparatively rough country. What is one of the highest hills in Northern Ontario, known as Maple Mountain, occupies parts of the Townships of Banks, Whitson and Rorke. Its elevation has been given as 2,000 feet above sea level. The mountain rises 950 or 1,000 feet (aneroid determination) above Anvil lake. The ascent is readily made along the surveyed line of the south boundary of Whitson, and there are few places in Northern Ontario from which a better view may be obtained. The country to the west of the mountain is much more rugged than is that to the east.

ROCKS OF THE AREA

The rocks have been divided according to the following scheme of classification:

Glacial and Post Glacial

Boulder clay, sand, gravel, clay.

Great Unconformity

Pre-Cambrian

Keweenawan

Nipissing diabase and gabbro.

Igneous Contact

Cobalt Series

Arkose, quartzite, conglomerate, greywacké and greywacké slate.

Great Unconformity

Laurentian

Granite, syenite and gneiss. These rocks are older than the Cobalt series, but their relation to the Temiskaming series is not known.

Igneous Contact

Keewatin

Altered greenstones.

Keewatin. The only areas of Keewatin greenstone met with were in the township of Tudhope. On lot seven, concession three, the rock is in places a rather coarse amphibolite, consisting almost wholly of green hornblende, occurring for the most part in grains about one-eighth of an inch in diameter, and also in fibrous masses.

*Report of Canadian Geological Survey, 1897, pp. 22 I, 268 I.

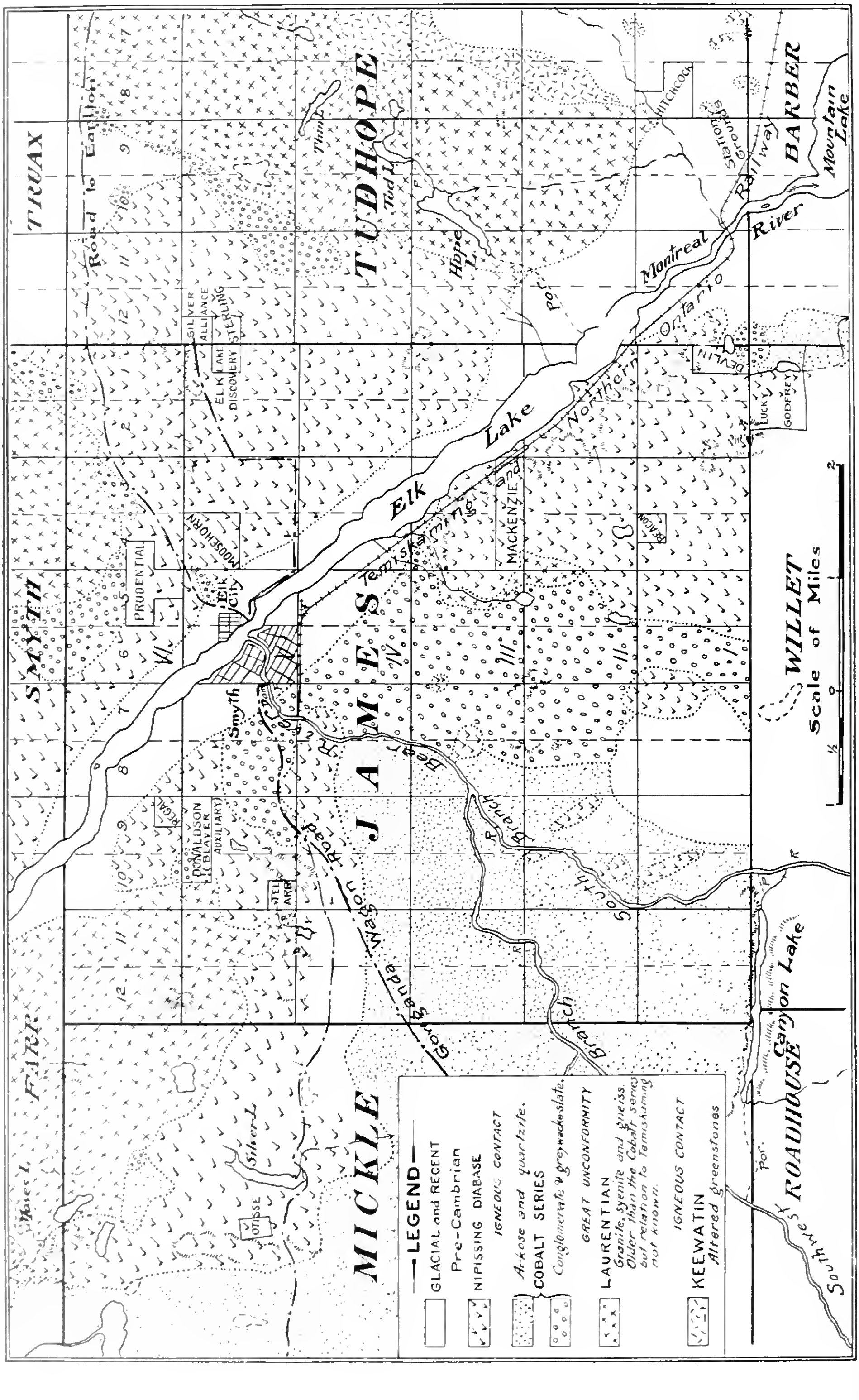

Fig. 63.—Area adjacent to Elk lake, Montreal river.

Small amounts of epidote and quartz are also present. In other places it is a dark, grayish green, fine-grained variety, which under the microscope is seen to consist mainly of small rods and irregular grains of green hornblende, together with allotriomorphic grains of twinned (and untwinned) feldspar, epidote, quartz and chlorite.

Torsion cracks are met with in places but they are not as large as those generally seen in the Cobalt area. Good examples of what is known as "ellipsoidal structure" are seen, especially on one outcrop in the centre of the square mile formed by lots seven and eight, concession three, Tudhope. The jasper-iron formation, characteristic of the Keewatin, was not met with.

Laurentian (?) The rocks classed under this head consist of coarse-grained granite, granite gneiss and syenite gneiss, many exposures of which are seen in the township of Smyth. The relationship to the Keewatin is splendidly seen on the north

Fig. 64.—Looking southwest from the top of Maple mountain, Township of Rorke, thirty miles west of the town of Cobalt.

half of the lot line between lots seven and eight, concession three, township of Tudhope. The granite here is a uniform, coarse-grained, pink variety, similar to that exposed about four miles to the west on lots four and five, concessions two and three, James township. It clearly invades the greenstone, and thousands of granite dikes from a foot or more down to a fraction of an inch are found ramifying in all directions through the greenstone. The light color of these dikes contrasts strongly with the dark green Keewatin. Angular fragments of greenstone have been caught up and included in the Laurentian. The mineral epidote, with its peculiar yellowish-green (sometimes called pistachio-green) color has been developed in the greenstone at its contact with the granite.

These granitic rocks are older than the Cobalt series, but their relation to the Temiskaming series, which is not exposed in the area, is not known. The granite may therefore be of the same age as that known as Lorrain.

Cobalt series. The Cobalt series consists of (1) conglomerate, greywacké and

greywacké slate; (2) arkose and quartzite. The conglomerate, greywacké, etc., of group (1) is exposed in many places in James township, and the arkose and quartzite are seen on Maple mountain. Both groups of rocks are similar to those in the Cobalt area proper, and in Lorrain township, but in the Montreal river area an unconformity has not been discovered between the two groups. In rare cases the arkose and quartzite become conglomeratic owing to the presence of white quartz pebbles.

Relation Between Cobalt Series and Granite

The unconformity between the granite and conglomerate is exposed on lots 4 and 5 in the second and third concessions of James township, on the east shore of "Deserted" lake. At the contact the conglomerate holds pebbles which are exactly similar to the underlying granite. The unconformity is very clear.

Diabase and Gabbro. These rocks are economically the most important in the area under review, because the cobalt-silver veins occur in them. Their exact age is not known, but where their contacts with the other rocks have been met with they are seen to penetrate them, and are therefore the youngest series in the field. Like similar rocks at Cobalt, the Nipissing diabase, they appear to be in the form of sheets or sills, and we saw no evidence of surface flows. At the southwest corner of lot ten, concession five, James township, there is a small area of quartzite or arkose. It lies at the foot of a diabase hill which showed a height of 120 feet by aneroid barometer. The diabase overlies this fragmental material. The actual contact is 450 feet east of the northwest corner of the northwest quarter of the north half of lot ten, concession four. The arkose floor upon which the diabase rests dips gently to the southeast, and it may be traced south of the concession line for about a hundred feet. At the immediate contact the two series have been fused together but otherwise the arkose does not appear to have been altered. The structural relationships here appear to show that the diabase is in the form of a sheet.

Other contacts with the diabase are as follows: On the southwest quarter of the north half of lot ten, concession five, James township, it is seen to invade the Laurentian gneiss. At the southeast corner of the northeast quarter of the north half of lot five, concession three, James township, it also invades the granite. On the northwest quarter, north half, lot four, concession five, James township it is seen to be younger than the Cobalt series. On the west shore of a small lake known as Beaver, in the township of VanNostrand, the diabase is seen to be younger than the quartzite. The latter, however, in this case overlies it.

The Nipissing diabase of the Montreal river presents somewhat greater variety than that of the silver area at Cobalt. It is usually medium in grain, but varies from fine grained types to those in which some of the pyroxene individuals are an inch in length. In some cases it shows very marked magmatic differentiation, that is to say it may pass into more acid types, having the chemical composition of syenite or even granite. An example of the latter is seen on the north end of Darby lake, township of Whitson. Frequently a pink feldspar develops which gives the rock a reddish appearance. Sometimes this feldspar is present in large amount. Such a facies occurs on White Bros.' mining claim (T R 207), township of Whitson. A thin section of the latter showed the rock to consist of an acid plagioclase and hornblende, together with a little augite, quartz, titanite and ilmenite. The feldspar is nearly all striated, and shows extinction angles under 15 degrees. Mr. A. G. Burrows separated this pink plagioclase from the rock and analyzed it with the following result:

SiO_2	67.76	
Al_2O_3	17.86	
CaO	2.37	
MgO	.27	
K_2O	2.48	
Na_2O	6.87	
FeO	1.6	
		99.21

Regarding the variety of this feldspar, Mr. Burrows says: "The high per cent. of silica would indicate albite, and there is also very likely a little orthoclase, as I noticed there seemed to be a very slight difference in the reddish portion of the sample, some parts being pinker than others. The alumina seems low for an albite and quite low for an oligoclase-albite, but it may be partially replaced by iron oxide. I simply calculated all the iron to ferrous oxide."

In other instances the diabase series carries quartz in micrographic intergrowth with feldspar, resulting in a quartz-diabase. Such an example is found at the southwest corner of lot four, concession six, James township. It consists essentially of plagioclase, augite and micrographic intergrowths of quartz and feldspar. The plagioclase occurs in rods and stout prisms, and the ophitic texture is marked. The augite is pale brown and non-pleochroic, and has partly altered to green fibrous hornblende and chlorite. The micrographic intergrowths of quartz and feldspar crystallized out last. On the lot immediately to the south the rock is also a quartz-diabase.

On the west shore of Bergeron lake, township of VanNostrand, there is an interesting dike cutting the quartzite series. Its position is indicated on the map. It begins at the northeast corner of J S 163, and can be traced northwest a quarter of a mile, showing a width of 75 feet. It is coarsely porphyritic, the phenocrysts of plagioclase sometimes having a length of two inches. Under the microscope the ground mass is seen to be made up of rods of plagioclase, pale brown augite, olivine and magnetite (or ilmenite). The texture of this ground mass is distinctly ophitic. The dike is a porphyritic-olivine-diabase.

We found a similar rock on the southeast end of Kerry lake, township of Van Nostrand.

Glacial and Post-Glacial. Boulder clay, sands, gravels and clays cover much of the area. The glacial striæ on top of Maple mountain are from 1 to 15 degrees west of north, whereas on lower altitudes they are usually some degrees east of north.

Notes on Veins

The silver and cobalt bearing deposits, all of which are found in the diabase, may be divided into two types, of which the first mentioned predominates, but has not proved to be of economic importance: (1) aplite dikes; (2) calcite veins. It would appear that there is no hard and fast line of division between the two types. The aplite dikes have the composition of granite, but are finer in grain and contain few colored constituents, like mica or hornblende, etc. A thin section from a dike in Smyth township (southwest quarter, south half, lot eight, concession two) was studied under the microscope. It is seen to consist of irregular grains of quartz and feldspar. A few grains of epidote occur. A small amount of calcite is present; this is seen to be younger than the other parts of the dike, because it occurs in cracks and ramifies between the grains of the quartz and feldspar. A vein on the Currie claim, on Hubert lake, township of Farr, also shows that the calcite is later than the quartz or feldspar. It is possible that this relationship does not always hold. On the shores of Silver lake, township of Mickle, the calcite in some of the veins was deposited later than the quartz. The latter has crystallized in prisms more or less at right angles to the walls of the crack and calcite has later on come in, together with certain copper sulphides (bornite and chalcopyrite). Native silver when present was probably deposited with the calcite. Thin sections from other aplites in Tudhope and Farr sometimes show quartz and feldspar in micrographic intergrowth. Chlorite is also sometimes present, apparently secondary after some ferro-magnesian constituent.

These aplite dikes are supposed to have been formed by cracks appearing in the diabase as it cooled and contracted; they were subsequently filled with vein or dike material, which probably came from hot solutions (aqueo-igneous) given off by parts of the diabase still molten. Small scales of native silver occur frequently in the aplites.

(It is interesting to know that veins or dikes carrying cobalt, somewhat similar to those of the aplite of the Montreal river area, are found in South Africa. The geolo-

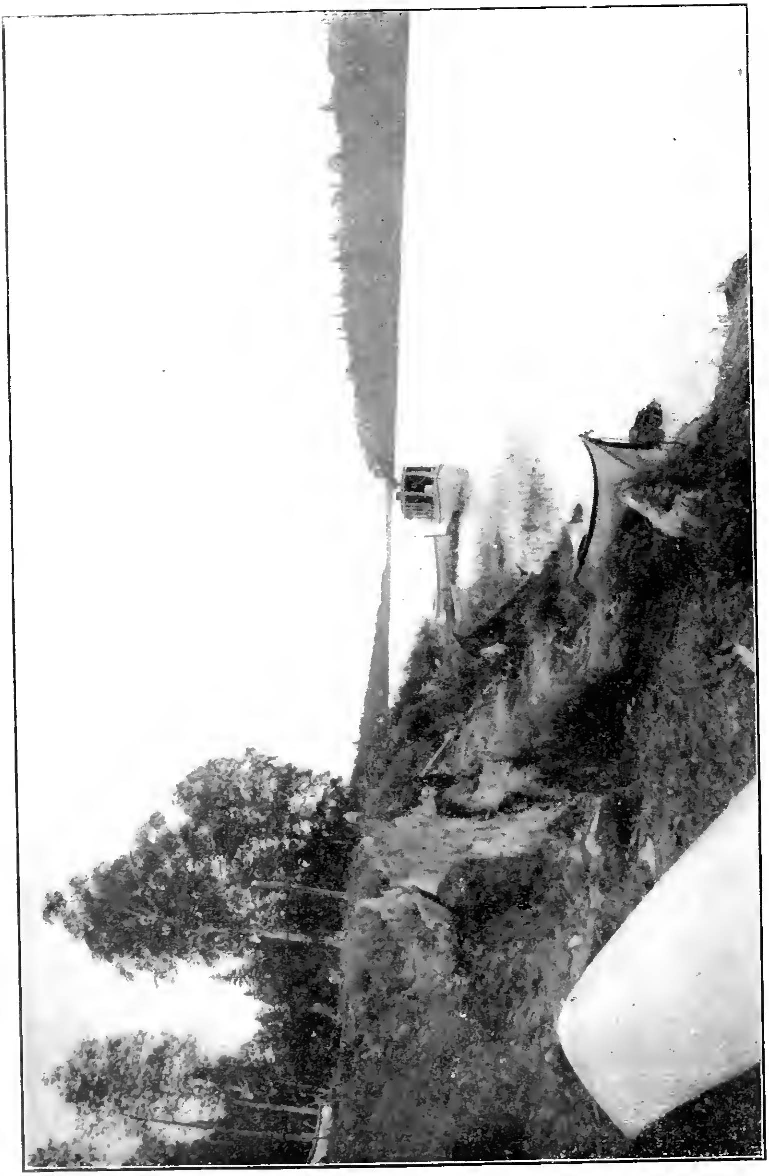

Fig. 65.—A stretch of Montreal river, Elk lake.

gists who have studied these veins or dikes in both Ontario and South Africa have come independently to the conclusion that they are probably of igneous origin. A brief description of the South African veins is given on a following page. W. G. M.)

Most of the calcite veins (type 2) are similar to the veins at Cobalt, save that the former sometimes contain the mineral barite, which is not known to occur at Cobalt.

The development work performed on the properties at Elk lake up to the end of the year 1907 was not extensive, but if information is desired on this point it will be found in the sixteenth Report of the Bureau of Mines, pages 125-127. Since that year work has been carried on at various times on several properties, concerning which the following notes have been taken from information supplied by Messrs. E. T. Corkill and A. G. Burrows.

At several properties where there were good surface showings the underground development did not show workable deposits. A discovery in 1912 of a vein on the Donaldson property, James township, near the 100-foot level, which carries high-grade silver ore, has revived interest in this section, while the construction of the branch line of the T. & N. O. railway to Elk lake will facilitate the development on several claims on which to the present very little work has been done.

Donaldson

This property is situated on the N.E. ¼ of the N. ½ of lot 9 in the fourth concession of James township. A number of calcite veins have been located and several pits have been sunk. On No. 4 vein, which strikes nearly north and south and dips steeply to the west, a shaft has been sunk to a depth of 150 feet. This vein consisted of calcite, with copper pyrites and specular iron ore, in which some silver values have been reported on assay. This vein dipped from the shaft at 90 feet, and another vein two inches wide, which contained smaltite and native silver, came in on the east side of the shaft, and was followed to the 150-foot level with short drifts at 100 and 150 feet. Some high-grade ore was taken out and bagged during this development. A main working shaft is now being sunk 50 feet west of No. 4 vein, and to the south of No. 2 a cross vein from No. 4. The property was being equipped with two 80-h.p. boilers, an 8 x 10 hoist and one-half of a 16-drill compressor.

Regal

The Regal adjoins the Donaldson to the north. Here two shafts have been sunk on calcite veins. The northerly one had been sunk 120 feet on the inclination of the vein. The intention was to sink to the 150-foot level and cross-cut to other veins which showed on the surface. At this property there is a 40-h.p. boiler and a 6 x 8 hoist.

Moose Horn

At this property some development work was being done on the south part of the group of four claims. The mining development has been described in recent reports by Mr. E. T. Corkill in Bureau of Mines' Reports.

Prudential

A shaft was being sunk on this property near the Moose Horn line. It was down 30 feet on an aplite dike, which had been reopened, with the formation of a smaltite vein. Where exposed at the bottom of the shaft the smaltite vein was about one inch wide, with an inch of aplite on either side. The smaltite carries variable percentages of silver. Some ore had been bagged during this development.

Beacon

At this property a shaft had been sunk to the 200-foot level, and a cross-cut was being run to intersect an E. and W. vein which showed on the surface.

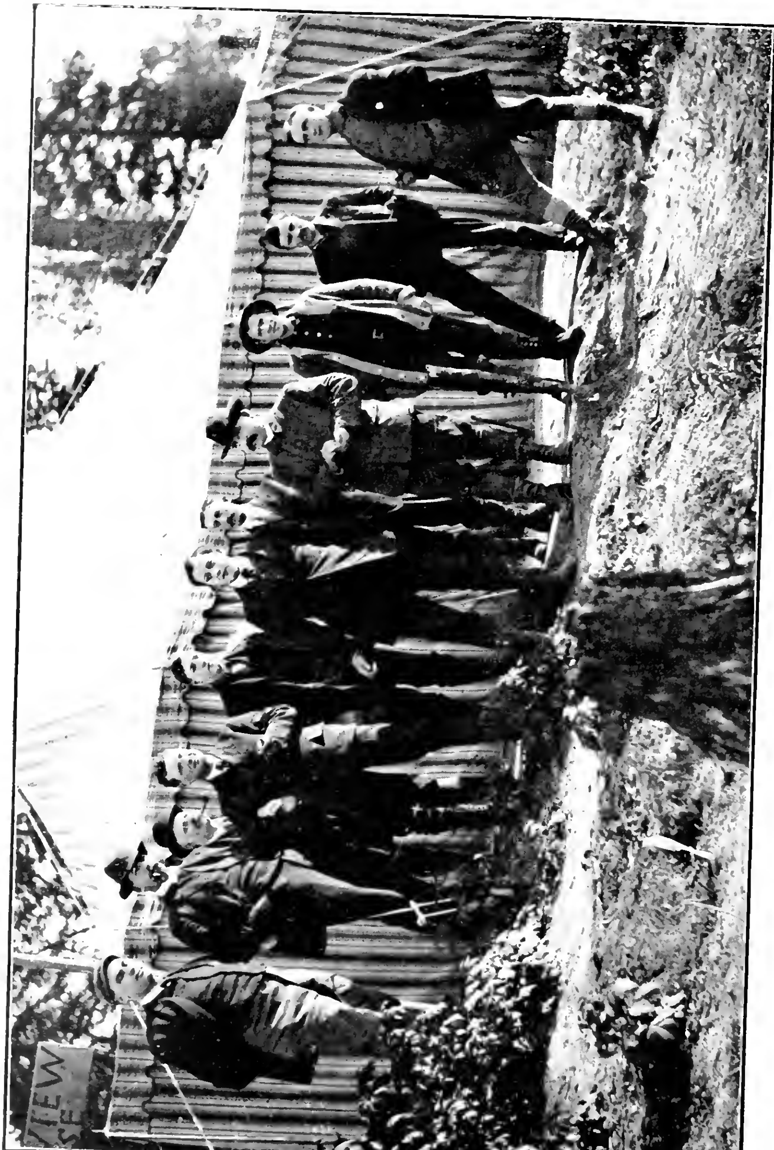

Fig. 66.—A group at Elk Like, October, 1907.

White Reserve Mines

In 1909 there were shipped from this property 6½ tons of ore.

Mackenzie

At the Mackenzie a shaft has been sunk 60 feet, with a cross-cut to the southwest. There were two veins which dipped to the northeast in the shaft. The cross-cut was made to intersect a vein which showed on the surface 35 feet from the shaft. This vein strikes N. 29° W., dips to the east, and has been developed by a shaft 30 feet deep and a long open cut and trench. The vein material is banded, consisting of aplite, with white and grey bands of calcite carrying copper pyrites. Native silver in small scales has been obtained in the vein of grey calcite. A number of veins occur on the property but most of them are undeveloped. An eight-inch basalt dike cuts the sill diabase and veins at the workings.

Auld Township

Native silver has been found in Auld township on the east side of the Montreal river. A great part of the township is drift-covered, but to the east of the river there is a diabase ridge which has a north and south extension. On the Hitchcock location (S. ½, lot 3, con. VI) there is a number of narrow east and west veins, in some of which native silver, with some smaltite and bloom, has been found. The wall rock of the veins is usually aplitic. On the westerly side of the easterly diabase ridge native silver occurs at two points in fairly coarse dendritic form. At the northerly exposure there is coarse-grained reddish aplite which is heavily stained with bloom. The aplite has more the character of a differentiation of the diabase than a clearly defined dike. At the other exposure where silver was seen there is a grey aplite, along one perpendicular surface of which there is native silver in dendritic form.

A similar occurrence was noted on the Bradley location (S. ½, lot 5, con. IV) which is on the west shore of Lepha lake.

The locality is easily reached from the Montreal river. Lepha lake is three-quarters of a mile east of the south bay of Indian lake, which is an expansion of the Montreal river.

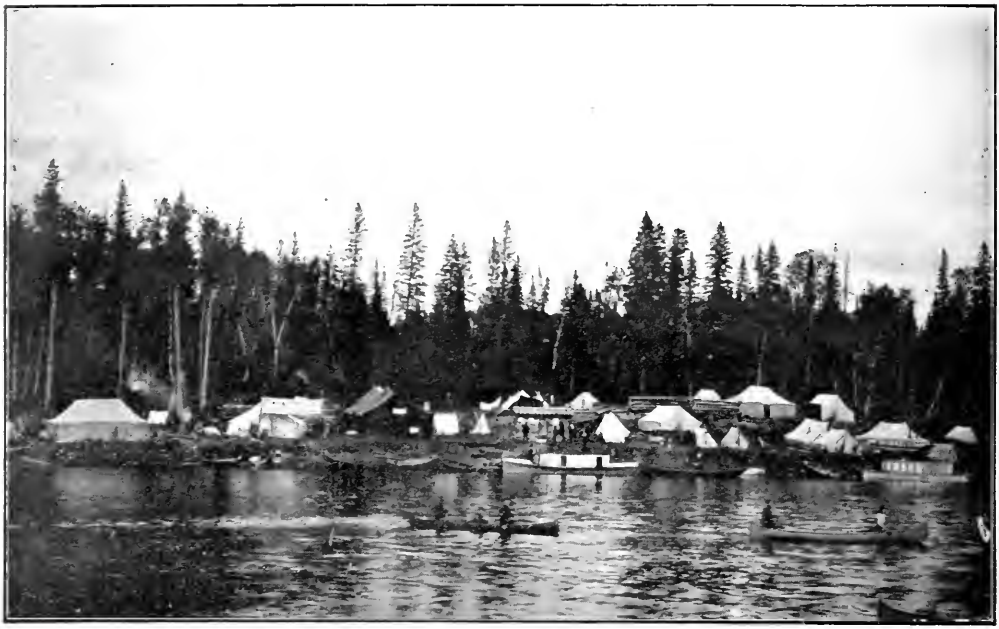

Fig. 67.—Elk City, James Township, summer of 1907.

Fig. 68.—Prospectors, with outfit, travelling up Montreal river, March, 1907.

THE GOWGANDA SILVER AREA*

By A. G. Burrows

The Gowganda silver area is situated in the Temagami Forest Reserve. Gowganda lake, which is the centre of the area, is 27 miles west of Elk lake. The latter is 40 miles northwest of Cobalt.

Owing to the distance from railways, the transportation problem has been a difficult one. During the open season the area was usually reached by steamboat from Latchford on the T. & N. O. railway, to Elk lake, and thence westerly over a wagon road to Gowganda, the journey occupying two days. During the past year a branch of the T. & N. O. railway has been constructed from Earlton to Elk lake.

Gowganda lake is the natural centre of the mining area, being within easy distance of the principal mines and prospects. A townsite known as Gowganda has been established on Bankers' bay, at the northeast end of the lake. It was partly destroyed by

Fig. 69.—The Post Office, Gowganda, April, 1909.

fire two years ago and has only been partially rebuilt. Several gasoline boats make regular trips on Gowganda lake.

Gowganda first attracted attention in the fall of 1908, when the discoveries on the Mann and Reeve Dobie became known. Prior to this, discoveries of silver had been made in the vicinity of Miller lake, on the Blackburn (Millerett) and Gates (Miller lake-O'Brien) claims.

The prospecting in the Montreal river area, which includes Gowganda, consisted in searching for areas of diabase, which appeared to be similar to the diabase exposed at Cobalt. These diabase areas occur at numerous places for many miles from Cobalt, and in a few instances workable deposits of silver ore have been found. It has not yet been shown whether these outlying diabase areas are parts of the sill exposed at Cobalt or whether they are parts of other sills which were formed at the same time as the Cobalt sill. Undoubtedly all the sill diabase outcrops can be considered to be of the same age.

*This report on the Gowganda area may be considered to be the second edition of that which was published with Part II. of the 18th Report of the Ontario Bureau of Mines. A colored geological map of the area accompanies this volume.

MAP
OF PART OF THE
GOWGANDA SILVER AREA

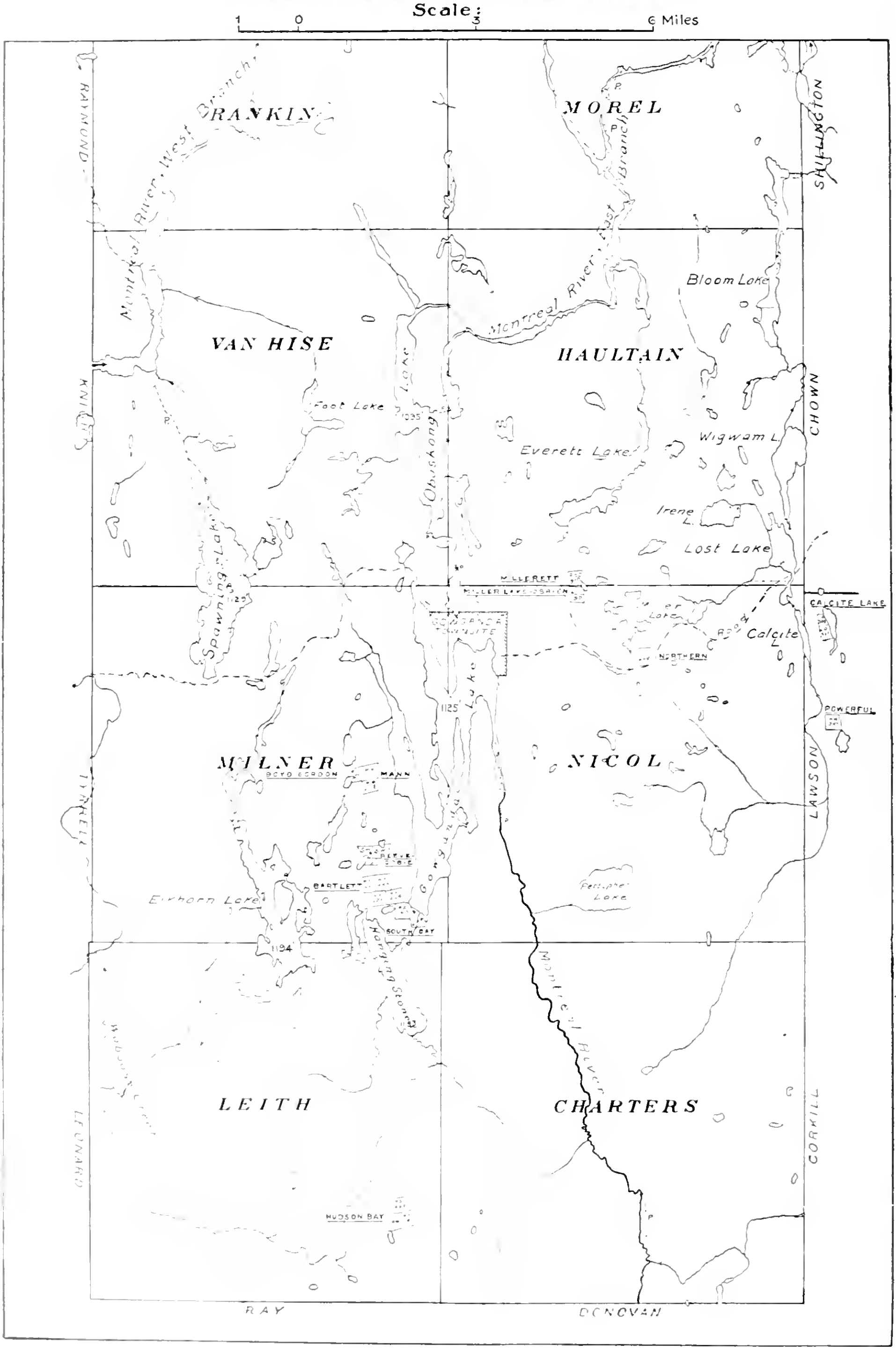

Fig. 70.

Fig. 71.—South end of Long Point lake, from government road—elevation, 1,040 feet.

Fig. 72.—Dog team on Gowganda lake.

The older rocks, which at Cobalt contain the great number of productive veins, have not up to the present time proved of great economic importance in the Montreal river area. The greater part of the production of the Millerett mine, however, has come from the conglomerate overlying the diabase sill.

Topography

The general character of the surface of the country is quite similar to that of other portions of northern Ontario which has been scored by recent glaciation. Viewed from hilltops the surrounding horizon presents a series of gentle undulations, with here and there a break or prominent hill. In detail, however, the surface is very rough and broken and different geological formations present some differences in surface contour. Rocky ridges alternate with swampy depressions abounding in small, swampy lakes, in much of the area. The larger lakes usually have considerable rocky shore line and are quite clear.

Generally the longer axes of the lakes are north and south, as this is the prevailing direction of the ridges. This north and south trend is particularly noticeable in the diabase occurrences and the general configuration of the country would seem to date from pre-Cambrian times. The waters of this area flow northward and there is a marked parallelism in the lake systems.

The most prominent features are the diabase, conglomerate and greywacké ridges, whereas the Laurentian and Keewatin generally occur as low rounded hills. The highest elevation was obtained to the southwest of Spawning lake in the greywacké range, which is 400 feet above the general level, or about 1,550 feet above sea level. The conglomerate hill to the northeast of Obushkong lake is 200 feet high and the diabase ridge on the long point in Gowganda lake is also 200 feet at its highest. Gowganda lake is about 1,125 feet above sea level.

Glaciation

The marks of glaciation, varying from fine striæ to broad grooves or rounded hummocks, are evident at many points. The ice mass moved about due south in this area Immediately west of Myrtle lake the glacial striæ are S. 10° E. Mag. and about three miles south on the Crawford claim, H S 339, they are S. 2° W. Mag.

Superficial Deposits

The superficial deposits consist chiefly of sandy loam, sand and gravel. The area lies a short distance south of the southerly limit of the northern Ontario clay belt. Very little of the soil would be suitable for agriculture except in small patches. Jack pine plains and rolling sand ridges are characteristic of much of the south part of the area, while spruce and dead tamarac swamps form a considerable part of the northeast part of Leith. The timber is chiefly white and black spruce, birch, balsam, jack pine and poplar. Red and white pine are seen in small groves in isolated parts. Around Gowganda lake the timber is generally small, but to the south in Leith and Charters there is timber of good commercial size.

In 1908 forest fires destroyed a large tract of timber along the east side of Charters, Nicol and Haultain, and west of Obushkong lake in Van Hise. Small patches have also been burned throughout the area.

ROCKS OF THE AREA

All the rocks of this area may be referred to the pre-Cambrian division and correspond to the scheme of succession as worked out by W. G. Miller in the Cobalt area. They may be tabulated as follows:

Nipissing Diabase

Igneous Contact

Fig. 73.—View from high hill to the northeast of Obushkong lake, showing Davidson and Obushkong lakes.

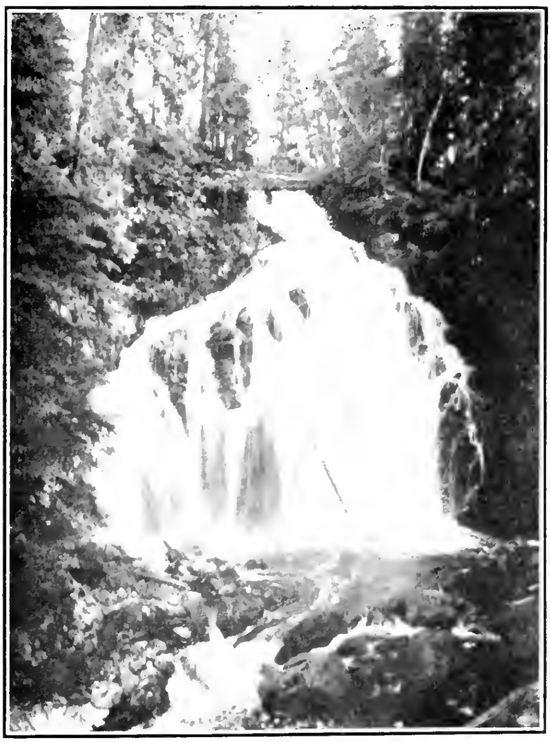

Fig. 74.—Bridal Veil Falls, east branch, Waboose creek.

Cobalt Series

Quartzite, arkose, upper conglomerate, greywacké-slate, quartzite, lower conglomerate.

Great Unconformity

Laurentian

Syenite and granite, intrusive into the Keewatin but not into the Cobalt series.

Igneous Contact

Keewatin

An igneous complex, consisting chiefly of altered basic igneous rocks with some light-colored intrusives and iron formation.

The Temiskaming series, which occurs at Cobalt and Porcupine, was not recognized in the area shown on the accompanying map, but rocks belonging to this series were observed in Midlothian township, 18 miles northwest of Gowganda lake, by James G. MacMillan.*

The oldest rocks comprise essentially the greenstones and green schists of the Keewatin. They show evidence of being largely altered basic igneous rocks. These have been much intruded by light-colored or acid dikes, which have also been much metamorphosed, and now show as bands in the darker rocks. In parts of the area these light-colored rocks are in excess of the other varieties. Bands of iron formation occur at isolated points to the west of Elkhorn and northwest of Gowganda. All of these types have been intruded by late basic dikes, some of which may correspond to the Nipissing diabase.

The Keewatin rocks are both massive and schistose. Where banded or schistose they are always highly tilted. Sometimes they are highly fissile and again platy, breaking in flat fragments an inch or so in thickness. Where these are very fine-grained, they may be distinguished by their steep, almost vertical, dip from similar appearing rocks in the Cobalt series, which for this area have a low dip. Spheroidal weathering in greenstone was observed to the east of Foot lake in Van Hise township.

The prevailing strike of the Keewatin schists is east and west, and in this direction they are often crumpled or folded.

Some Types of Keewatin

A greenish weathering massive rock occurs to the north of Miller lake. A section of a sample from the south line of R S C 87 is altered to scaly and fibrous green hornblende and may be called an amphibolite. To the east of the lake there is much hornblende and chlorite schist.

To the west of Leroy lake the greenstone is much altered and has a dull green, mottled appearance when freshly broken. A section shows much chlorite, epidote, in grains or veinlets, fibrous hornblende and other secondary minerals. This rock, which is rather massive, passes to the west into schist, striking N. 65° E. and dipping 70° N.

About three-quarters of a mile south of Leroy lake some of the rock is an altered porphyry, much sheared and schistose in part. Under the microscope it proves to be an altered feldspar porphyry. The phenocrysts of feldspar are much crushed, and occur in a groundmass of granular quartz and feldspar. To the west of the porphyry is a belt of fissile chlorite schist, much intersected by small veinlets of white quartz.

Hornblende schists and amphibolite occur to the south of Cartwright's camp on Everett lake. Part of the rock is banded, breaking in plates. A section shows green fibrous hornblende the predominating mineral, with grains of zoisite, epidote and a little chlorite.

*Report of Chief Engineer, T. & N. O. Railway, 1910-1911. *See* Chap. I.

West of Obushkong lake there is considerable hornblende schist and associated serpentine rock, which is much weathered to a rusty brown color. In thin section it appears to be chiefly serpentine, with a separation of magnetite. A meshlike arrangement of highly polarizing minerals, in part fibrous hornblende, surrounds the serpentine. The origin of the serpentine was not determined. Serpentine rocks also occur to the north of Serpentine lake and are described by Mr. W. H. Collins as an alteration from olivine rocks.

Immediately to the southeast of Dinny lake is a hornblende rock which is cut up by small veinlets of actinolite. A section of the rock shows alternate bands of fibrous green hornblende and colorless serpentinous material. To the east of this, on the north line of H R 256, the formation is largely serpentine.

A light-colored acid rock is interbanded with the greenstone to the west of Obushkong lake. It is very fine-grained in appearance, consisting largely of crushed quartz and feldspar, with glistening scales of white mica. The dark mineral is chlorite, which is drawn out in fine lines and gives a gneissic texture to the rock.

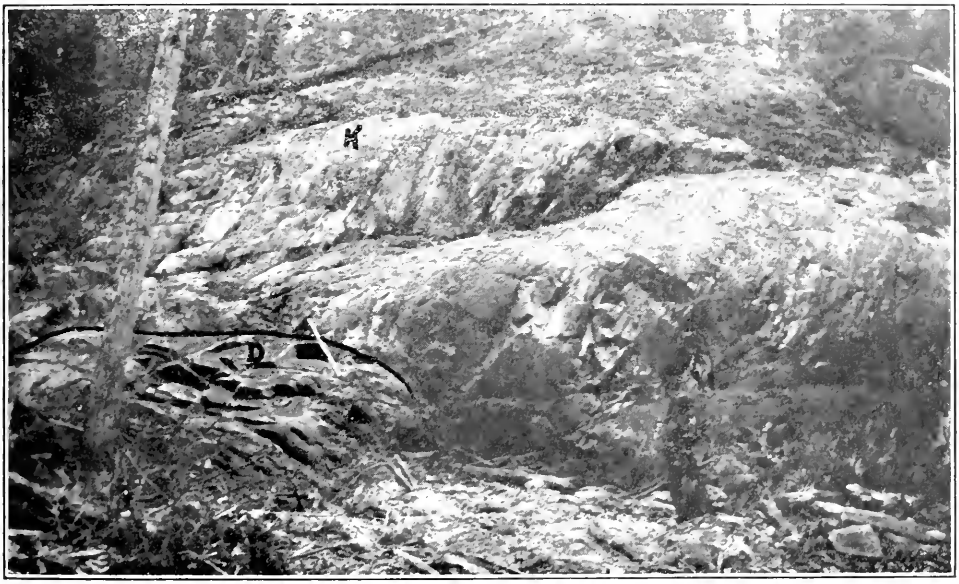

Fig. 75.—Keewatin (K) intruded by diabase (D) east of Cartwright's camp, Everett lake.

On W J 15, one of the Leroy group of claims near Leroy lake, a diamond drill hole was put down at an angle of 67 degrees. This passed through quartz diabase of various grain, but uniformly dark-colored, for 485 feet, when it passed into Keewatin and was continued for 12 feet. The Keewatin is a fine-grained greenstone, which under the microscope proves to be an altered diabase, as the ophitic texture of the diabase may still be discerned.

Iron formation occurs to the west of Elkhorn lake, along the boundary line of Milner and Leith, showing as bands of red jaspilyte. The ore, which is very lean, is specular hematite and magnetite. The bands are only a few inches to a few feet wide and are associated with an amygdaloidal trap, which represents the lava from an old Keewatin eruption. The vesicles of the original lava are now filled with later minerals, the most abundant of which are quartz, calcite and epidote. Under the microscope the flow structure of the rock is beautifully shown in the somewhat parallel arrangement of the minute rods of plagioclase feldspar.

Another band occurs to the northeast of Gowganda on the Cryderman claim, W D 962. Here the formation is alternately lean magnetite and dark grey siliceous bands. No commercial ore was seen at any of the outcrops.

Dikes in the Keewatin

North of Brett lake are several narrow dikes of a reddish brown lamprophyre. The phenocrysts are augite set in a groundmass of feldspar and scales of fibrous hornblende. Calcite, in grains and veinlets, is also seen.

To the east of the same lake are diabase dikes which are rather fresh looking and may correspond with the typical sill diabase of the area. A section from one of these dikes shows plagioclase feldspar and hornblende as the chief constituents, with some grains of epidote, and magnetite altering to leucoxene.

Fig. 76.—Iron formation (1) intruded by quartz porphyry (P) on mining claim W. D. 962. Northeast of Gowganda.

To the northeast of Gowganda lake, occurring over a number of claims and much intermingled with green schist and iron formation, is a whitish and reddish porphyry, which in part has well marked phenocrysts of quartz and again is felsitic in appearance. A section of a sample from the south line of R S C 123 shows most of the phenocrysts to be quartz which have corroded outlines and are partially crushed. Some ragged outlines of plagioclase are also seen. The groundmass is granular quartz and feldspar with a little chlorite. Much of the rock is quartz porphyry. It intrudes the green schists and iron formation and may be of Laurentian age. In this area the green schists, porphyry and iron formation are much confused and all are cut by narrow dikes of diabase, so that a division of the different formations was impossible.

Crushed Syenite

Along the east shore of Dinny lake and at points to the north end of Davidson lake is a narrow fringe of a reddish rock, hardly a chain wide in any place, which

under the microscope appears to be a badly crushed syenite. It may have been a dike which later became a fault plane which granulated the rock. A sample of a coarse variety east of Dinny lake is largely plagioclase and orthoclase, badly crushed with many cleavage cracks and showing wavy extinction. Throughout the whole mass are veinlets of chlorite and epidote.

Laurentian

Probably the most of the rocks here classed, for convenience, as Laurentian are of similar age to the Lorrain granite of Cobalt. They are largely flesh-colored and grey granites and syenites, grading into each other. There is a tendency in small areas to pass into gneiss, but this structure is only evidenced by the drawing out of constituents in lines. The rock has not been subjected to folding and intense metamorphism seen in other localities. The most common variety is a hornblende granite,

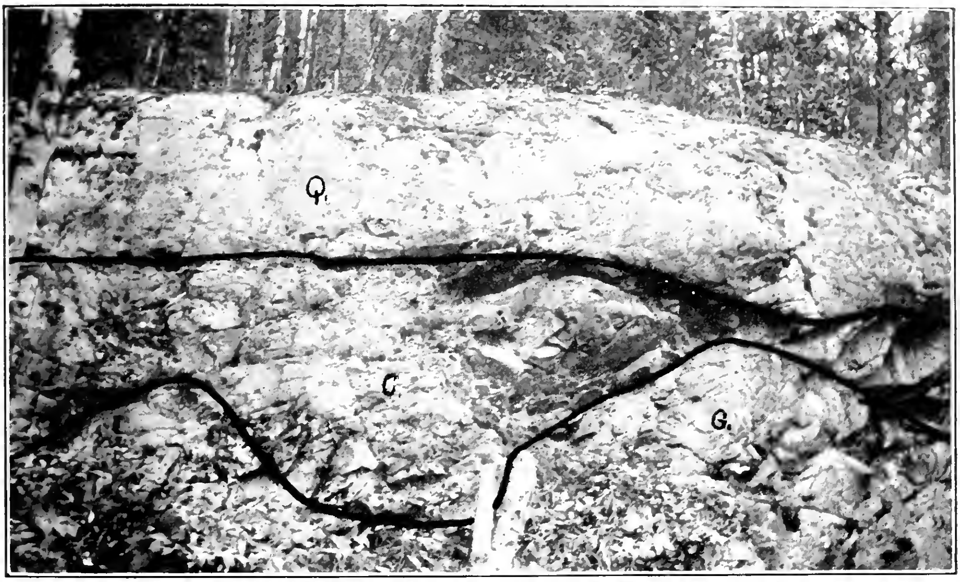

Fig. 77.—Contact of Laurentian and Cobalt series, east shore of Bloom lake. (G) granite, (C) angular and rounded fragments of granite, (Q) quartzite.

generally pink or flesh-colored. A section of a sample from west of Bloom lake is a hypidiomorphic mixture of quartz, feldspar (orthoclase and acid plagioclase) and green hornblende, with a little sphene, apatite and magnetite as accessory minerals. This rock may be traced to the southwest, where it gradually passes into a hornblende syenite, around Everett lake, and extending west to Davidson lake. It intrudes the Keewatin at many points to the west of Everett lake and near Cartwright's camp. Another common variety is a grey biotite granite, which is intermingled with the hornblende granite.

A porphyritic syenite occurs to the northeast of Wilson lake. Where it approaches the basic Keewatin rocks, it becomes darker in color with blotches of basic material which have been absorbed from the Keewatin. The porphyritic character is well marked on the weathered surface where the feldspar has been bleached out. In thin section much of the feldspar is idiomorphic and has a zonal structure due to the regular arrangement of included minerals. The ferromagnesian minerals are green hornblende and a little biotite altering to chlorite. Quartz is present in small grains.

Cobalt Series

This series covers a large part of the area and presents a great number of types of rocks. There is often a gradation from a fine-grained slate to a quartzite or conglomerate and a separation is difficult. These rocks have been little changed since their deposition. No secondary cleavage has been developed and the parting in the slaty varieties corresponds to the stratification.

Greywacké, in part quartzitic, occurs over most of the west parts of Leith, Milner and Van Hise. Conglomerates are seen along the west shore of Gowganda lake, on the long point of the lake, and at frequent points to the east of the lake.

Typical arkose and quartzite are well developed along the east and southwest shores of Obushkong lake and in the valley stretching southward to Gowganda lake. They include most of the township of Charters and the eastern part of Nicol and also

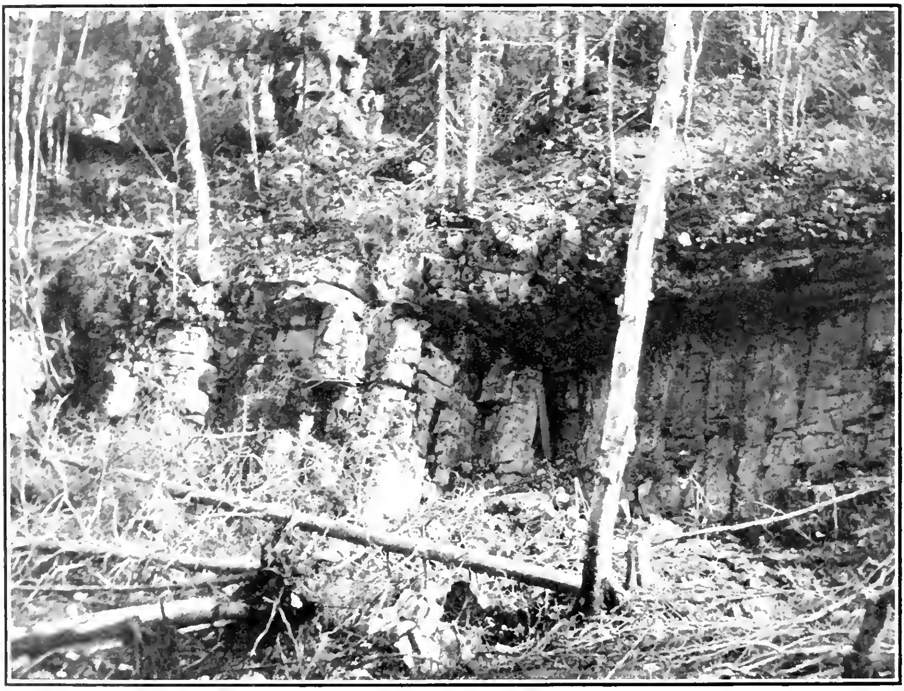

Fig. 78.—Banded slaty greywacké overlain by brecciated greywacké, with easterly dip. Southwest of Myrtle lake.

the large island in Gowganda lake. This series of rock is generally coarse-grained and thick bedded, so that its dip is not easily recognized.

Finely banded slate-like greywacké occurs to the southeast of Myrtle lake, on the east side line of T C 156, and at several other points. It is often brecciated as an autoclastic rock. This is well seen at the locality above mentioned, where the slate shows in a bluff dipping to the east. The top layer of the cliff is much brecciated and overhangs the lower normal slates which have been crumpled away. Similar breccia is also seen west of Frying-pan lake, on Bulsch lake and on the government road a mile east of Lost lake. These occurrences are all near the later diabase and the brecciation may be due to the diabase intrusion.

The prevailing dip of the Cobalt series is to the east at a low angle, generally not greater than 15°. Where the diabase has broken up as laccolites the sedimentary rocks have been tilted up more steeply. Along the contact of the diabase and the

rocks of the Cobalt series, extending across the long point in Gowganda lake, the spotted quartzite or slate seen on the north line of T C 27 dips to the west.

About half a mile north of Wilson lake in Nicol township the rocks of the Cobalt series dip gently to the west from the Keewatin. The succession is greywacké conglomerate, slate, quartzite and an upper coarse conglomerate which resembles the conglomerate along the west shore of Gowganda lake. This succession of strata is seen at other parts of the area. Sometimes the greywacké is underlain by a coarse boulder conglomerate, which is very similar in appearance to the upper conglomerate. The latest rocks are quartzite and arkose.

Unconformity at the Base of the Cobalt Series

At many localities in the area basal conglomerates and breccias occur in which the included fragments and boulders are syenite, granite, greenstone, porphyry, diabase, etc., which are found in the vicinity in place.

Fig. 79.—Basal conglomerate, Cobalt series, overlying granite, and containing boulders of granite. Northwest shore of Obushkong lake.

On the northwest shore of Obushkong lake, just north of the north line of L M 116, is a small patch of conglomerate with the underlying Laurentian showing through it. The conglomerate has rounded and angular pieces of the local Laurentian and also fragments of a rusty weathering diabase which cuts the Laurentian immediately at the conglomerate contact.

On the east line of W D 961, northeast of Gowganda lake, the basal conglomerate is composed almost entirely of fragments of grey porphyry which underlies the conglomerate.

North of Wilson lake are patches of conglomerate on the syenite. This syenite has a characteristic porphyritic texture, and fragments of this rock form the main part of the conglomerate. Other contacts could be cited of a like nature, so that, for this area at least, the base of the Cobalt series is formed from material which is very local and not transported any distance.

Unconformity in the Cobalt Series

Mr. N. L. Bowen found an unconformity on the north line of H R 311, west of Obushkong lake, where greywacké and fine-grained arkose show in a bluff about twelve feet in height. At the base of the arkose are about two feet of a coarse reddish conglomerate containing some small pieces of greywacké which, under the microscope, prove to be the same as the underlying greenish rock, thus indicating a break in the deposition. A similar break was seen southeast of Flanagan lake, near the south line of H S 712.

West of Gowganda lake, and on the long point extending into the lake, an upper conglomerate with a coarse matrix occurs in considerable thickness. Similar conglomerate is seen in other parts of the area. The writer is not certain that the few feet of conglomerate seen below the arkose series on Obushkong lake is equivalent to

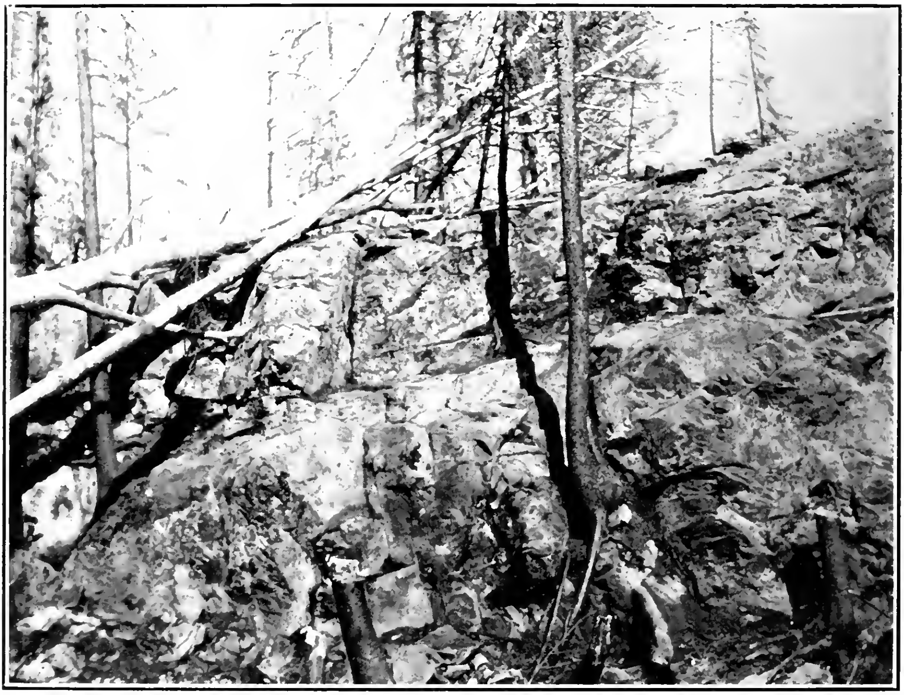

Fig. 80.—Unconformity between greywacké conglomerate and arkose (conglomerate). North line of H. R. 311, west shore of Obushkong lake.

all this conglomerate. Where there was any great thickness of conglomerate a search failed to show any inclusions when it rested on the underlying rocks. At some points there seemed to be an uneven surface and at others there did not seem to be any break. When the unconformities were seen they occurred very near the arkose series, with only a few feet of conglomerate material intervening.

In the map accompanying this report, rocks of the Huronian, now called the Cobalt series, have been distinguished by two colors, brown and yellow. The upper portion, shown in yellow, consists principally of quartzite and arkose, which will largely represent the Lorrain series of rocks exposed near Cobalt, while the lower portion, shown in brown, will represent the Cobalt series, consisting of greywacké, conglomerate, etc. The upper conglomerate may possibly belong to the upper or Lorrain series, but sufficient work was not done to separate it, consequently it is shown in the brown color.

Nipissing Diabase

The Keewatin, Laurentian and Huronian formations are all intruded by sills and dikes of diabase. The broad areas of diabase are sills which have spread out in or cut across the strata of the Cobalt series. At points the diabase has broken up into the overlying formations as laccolites.

In the Keewatin and Laurentian the intrusion is largely as narrow vertical dikes, a few chains in width.

The sill character of the diabase is well shown in that occurrence which extends north from the east side of Elkhorn lake to Logan lake. At points the diabase both underlies and overlies the slate and the sill dips to the east. The thickness of the sill in this area is about 400 feet. Just southeast of Crawford lake the diabase under-

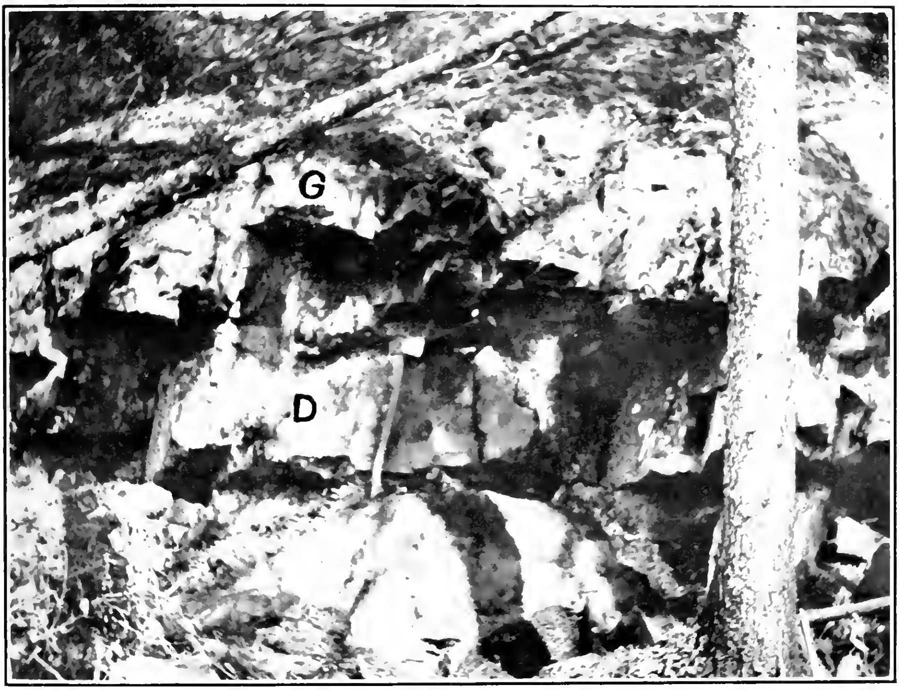

Fig. 81.—Greywacké (G) of the Cobalt series underlain almost horizontally by the Nipissing diabase (D). South of Logan lake.

lies the greywacké, with dip to the north. To the west of the Boyd-Gordon, the contact is in a valley, but the topography would suggest that the contact is rather steep and to the west. These contacts would indicate that the sedimentary rocks from this point west to the Elkhorn sill are underlain by diabase. At many points near the cooling surface the sill diabase has a marked columnar structure, which is developed at right angles to the dip of the sill.

The broad sill areas would all appear to be closely connected with one intrusion and at points to have broken up into the overlying formation, and, on erosion, have been exposed as more or less isolated areas. These areas have generally a north and south extension, and this is also noticeable in the narrow dikes.

The dike diabase has a very uniform character and grain, whereas the sill diabase shows much differentiation, ranging from basic phases through intermediate stages to reddish granitic rocks. In the same mass the texture may vary from a fine ophitic to a coarse granular or allotriomorphic character.

The normal diabase is generally of a dark greenish grey color. A sample from the north line of H F 204 shows labradorite feldspar set in augite, which is partially altered to green hornblende. Quartz in micrographic intergrowth with feldspar fills the interstices.

A sample from the west side line of H S 542, east of Crawford lake, is fine-grained and consists of plagioclase, largely altered to saussurite. The ferromagnesian minerals are green and brown hornblende, with a little chlorite. Quartz and feldspar in micrographic intergrowth are also present.

A section of a coarse phase of the diabase, which may be called a gabbro, from a shaft on W J 8 near Leroy lake, is essentially plagioclase altered to saussurite, augite partly altered to uralite and abundant intergrowth of quartz and plagioclase.

The red phase of the diabase, which has a very prominent development in parts of the sill areas, is abundant in the vicinity of Lost lake and to a lesser extent in other localities. It varies greatly in texture and color very locally, and is largely made up of a granophyric mixture of quartz and feldspar. In some coarse samples this structure can be seen in hand specimens. This red rock may be traced gradually into normal diabase, with many variations in the intermediate stage.

A section of a coarse, reddish brown granophyre from the south line of H R 405, east of Lost lake, is largely the granophyric intergrowth developed around stout prisms of acid plagioclase. The intergrowth, very fine at the centre, increases in size as it radiates outward, with much free quartz on the margin. Chlorite occurs in very minor quantity. A dark grey and fairly coarse sample from the wall of an aplite dike on the Lataif claim, just northeast of Flanagan lake, is more acid than the normal diabase type. The section shows it to be largely an intergrowth of quartz and feldspar, with some laths of plagioclase, secondary hornblende and calcite in minor quantity. The magnetite present is altering to leucoxene.

Later Dikes

The sill diabase has been intruded by later basic dikes in part of the area. West of Calcite creek, on the north line of H B 28, is a dike of olivine diabase about one chain wide which cuts the sill diabase quite distinctly. At its contact it is a very fine-grained basaltic rock, which becomes coarser rapidly and shows quite large phenocrysts of light greenish plagioclase in a diabasic groundmass of plagioclase, augite and olivine. This dike is very similar to that described by Mr. Bowen west of Obushkong lake and to other porphyritic dikes in the area, so that many of these narrow porphyritic dikes are evidently younger than the sill diabase.

A dike of later diabase cutting the diabase sill of the Cobalt area is described by W. G. Miller.* This dike is porphyritic and olivine-bearing, and would thus be similar to the later olivine diabase dikes of the Gowganda area.

A non-porphyritic quartz-diabase dike one chain wide cuts the sill diabase on T C 156, just south of Myrtle lake.

Mr. N. L. Bowen gives the following descriptions of some diabases from the Gowganda area:—

Small Dike Cutting Davidson Lake Sill

"The dike is fine-grained, showing slender laths of plagioclase averaging 0.3 mm. in length, ranging from acid labradorite to acid bytownite, and set in a groundmass of augite. Augite fills the interstices and is sometimes altered to a felt of needles of low birefringence with skeletons of iron ore. Black iron ore forms about 15 per cent. of the rock. No quartz could be found.

*Bureau of Mines Report, 1907, Part II., p. 64. *See* preceding page, chap. I.

Olivine Diabase Dike, West of Obushkong Lake, Cutting Huronian and Showing Large Phenocrysts of Feldspar

"The feldspar phenocrysts carefully determined are mainly andesine. . . . A narrow outer rim usually shows zonal intergrowth, with labradorite and andesine alternating. The groundmass consists of plagioclase, augite, olivine, apatite and iron ores. The plagioclase is mainly labradorite, showing zonal growth, with acid andesine forming the outer zones. The olivine is in small grains and most of it appears to have crystallized before the feldspar. A brownish augite fills the interstices between the feldspar laths in perfect ophitic structure. Apatite is usually abundant in long needles. No quartz or micropegmatite was found.

"In the examination of some sections of normal sill diabase, in addition to the normal augite, another pyroxene occurs in lesser amount, showing nearly always parallel extinction but in some sections as high as 10°. The maximum interference color is a pale yellow of the first order. The optical character is positive as in the

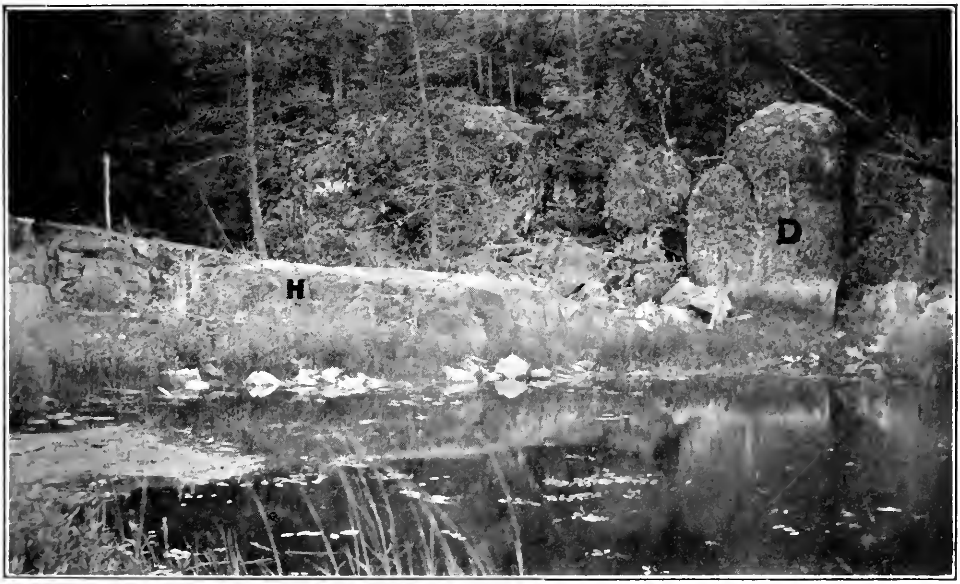

Fig. 82.—Contact of slate of Cobalt series (H), and Nipissing diabase (D), Bulsch lake. The slate underlies the diabase.

augite, and a faint pleochroism is shown. The pyroxene is probably enstatite. The occurrence of slightly oblique extinction in rare cases is to be explained in its wide axial angles."

Veins

With a few exceptions most of the promising silver-bearing veins have been located in the Nipissing diabase, unlike the Cobalt area where the great majority of the productive veins are in the conglomerate of the Cobalt series. The most conspicuous exception is the vein in the conglomerate on the Millerett property, which so far has proved one of the most important in the Gowganda camp. Native silver occurs in small quantity in the Keewatin near Miller lake, and strong veins of smaltite and niccolite have been found in the Keewatin and conglomerate. Generally the diabase has been more thoroughly prospected than the Keewatin or Cobalt series, which should be worthy of close attention near contacts with the diabase.

In the diabase itself the silver-bearing veins appear to be confined to the broad sills and much differentiated areas, rather than to the narrow dikes. The latter have not been fissured to any extent.

Many of the narrow veins seem to be closely associated with the solidification of the diabase, with the resultant cooling cracks being filled with vein solutions. The presence of aplite in many of the veins would indicate this. Sometimes one or both walls of the aplite pass gradually into the normal diabase. The veins which are the resultant of cooling repeatedly change their direction and fade away to mere cracks. Other veins appear to be the result of more extensive fissuring and may be followed on several adjacent claims in a fairly straight course. Native silver has been discovered on a great number of claims, but only a few of these have been shown to be of much commercial value.

In the diabase itself there are certain enriched areas. In the occurrence of diabase just west of Gowganda lake there are two such areas, the southerly one including the Reeve-Dobie, Welch, Bartlett, Burke-Remy and Crawford, and the northerly the Boyd Gordon, Mann, Silvers Limited, and Milne. To the north of this again, near Myrtle lake, there are a number of promising veins on the Dufferin mines and Bishop

Fig. 83.—Granite (G) intruded by Nipissing diabase (D), south of Bloom lake.

properties which show native silver, but at the time of the writer's visit no shipping ore had been uncovered.

East of Gowganda lake is a small area including the Millerett, Bonsall and Miller Lake-O'Brien, and, southeast of Miller lake, the Morrison, McKay, Chapelle and Leroy properties.

Another small area lies to the northeast of Flanagan lake in Leith, including the Sweet and Lataif claims.

There is a marked similarity in the occurrence of silver ore on many of the properties. The veins are usually quite narrow, widening in places to several inches and again pinching out to a crack rather abruptly. The ore occurs in short shoots or bunches in the vein, with portions of the vein quite barren. This has caused some difficulty at several properties in procuring any quantity of shipping ore. The diabase occasionally is very much intersected with mere cracks which are filled with sheets of native silver. This is particularly noticeable at the Reeve-Dobie—along the main fissuring—where much of the diabase would be good milling ore. In the Flanagan lake area some aplite dikes have been split open after solidification and solutions of calcite, smaltite, etc., deposited later. The vein filling is usually calcite with silver, smaltite, niccolite and occasionally native bismuth and bismuthinite. Copper pyrites is also seen in some of the silver-bearing veins, but more commonly occurs in veins which

have not proved of economic importance. Occasionally quartz occurs with calcite in the gangue, generally along the walls of the fissure. In some of the smaller veins the fissures have been entirely filled over short distances with smaltite, niccolite and silver. Some of the veins have been oxidized for a few feet in depth, but generally the undecomposed ore may be seen quite near the surface. An open leached-out crack occasionally is all the prospector at first finds which, on being followed down, frequently reveals a calcite vein.

In parts of the area there are some very strong calcite veins, some as wide as three feet, and which have been traced over several claims. These are usually quite

Fig. 84.—Trench, showing fissuring in diabase, on mining claim H. R. 250, west of Gowganda lake.

barren but show that there has been extensive fissuring in the diabase. An exception to this is the large vein on the Morrison, T C 315. This vein is reported to have been traced 2,000 feet and the writer saw it at several points uncovered with a width of from two to three feet of calcite. Near the camp this vein strikes N. 68° E. mag. It consists of a series of wide lenses, and had been opened up by a pit near the camp where, for a distance of eight feet, some rich ore consisting of silver, smaltite, niccolite and bismuth in calcite had been taken out. The ore occurs in a rich bunch at this point. At other points along the vein where stripped the writer did not observe a similar mineralization.

There is a wide calcite vein, with a strike similar to the above vein, on the Miller Lake-O'Brien property which cuts a north and south silver-bearing vein, proving it to be of later age. Many of the wide veins may therefore belong to a later system than those narrow veins which so frequently carry silver values.

In reference to the deposits in the diabase, it may be stated that several veins which carried good values in native silver at the surface have not proven to hold these values at depth and, in many cases, the silver content has entirely disappeared within forty feet, while the veins continue as strong as on the surface. Again, the veins themselves have disappeared at the same depth or narrowed to mere cracks. As the surface showings are usually rich over short distances with barren intervals or tightening of seams, this condition may occur in the vertical direction. There does not seem any reason why the values should not carry to a considerable depth, as some of the rich surface showings may be traced at intervals over several hundred feet.

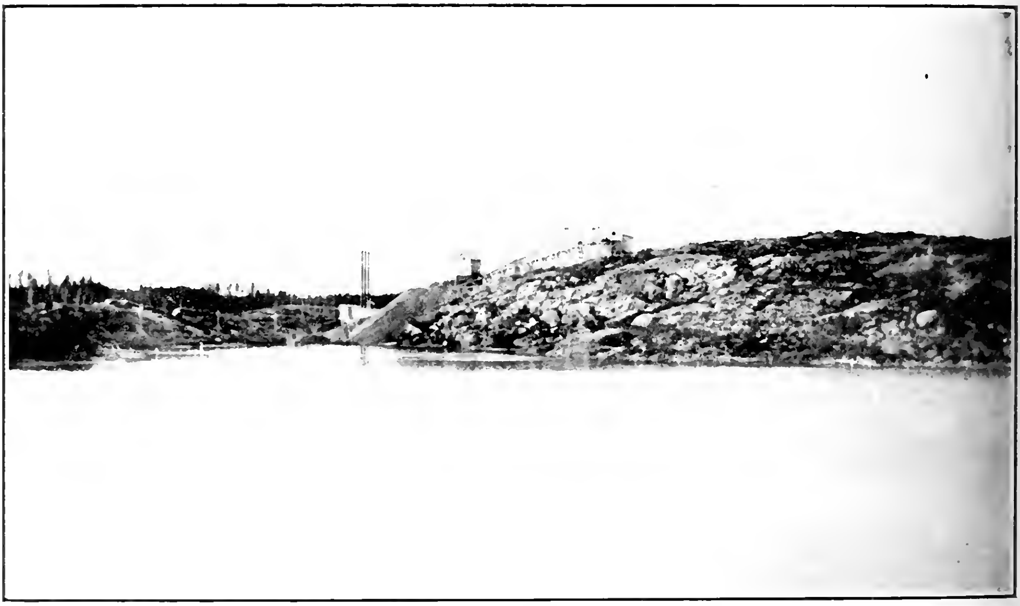

Fig. 85.—Millerett mine, showing stamp mill.

The Millerett Mine*

This property, R S C 95, formerly known as the Blackburn, is situated three-quarters of a mile northeast of Miller lake. Conglomerate, quartz-diabase and Keewatin greenstone occur on the property. Of these, only the conglomerate and diabase have shown silver-bearing veins. Twelve veins were found, five of which contained shoots of native silver, while the calcite and smaltite filling of two others showed silver on assay.

The principal vein is on the northeastern portion of the claim entirely in the conglomerate area. The strike is northwest and southeast and dip 70° to the southeast. This vein was traced on the slope of the hill for 300 feet. The conglomerate overlies the diabase sill.

An adit level was run into the hillside for a length of 253 feet, giving a back of 50 feet at the end. Near the entrance of the adit a vertical shaft was sunk 85 feet, and at the 70-foot level a drift was run to the southeast. The main ore shoot has a length of 150 feet, the vein averaging slightly over two inches in width and consisting

*For a further description of the Millerett mine and other properties at Gowganda, reference can be made to an article, "Gowganda during 1911," by G. M. Colvocoresses, Canadian Mining Journal, Vol. 33, No. 8, p. 256.

fine leaflets, impregnated the conglomerate for a width of two feet on each side of the vein. At other parts of the vein the filling is calcite, with smaltite in places. The great proportion of the ore obtained from the conglomerate was taken from above the 70-foot level, where the shoot was stoped to the surface. A smaller ore shoot in a winze below the 70-foot level was also stoped.

Next to the conglomerate vein No. 7 in the diabase was the most important, producing about 200,000 ounces of silver. The ore in the vein has been stoped from below the 150-foot level to the surface, the shoot narrowing towards the surface, while the pitch of the shoot is to the east. The diabase along the vein carried silver values along the fractures, giving an average of 18 inches of milling ore. Small amounts of silver were taken from other veins in the diabase, but these were only in stringers or short shoots. The veins in the diabase, with one exception, strike nearly E. and W., of calcite, smaltite and cobalt oxides, with native silver. Native silver, in specks and with the dip vertical or about 85° to the south. The diabase sill rises from the east

Fig. 86.—Camp, Millerett mine.

at about 30°. It shows a marked columnar structure which, in places, takes on a concentric or cylindrical character, the rock frequently breaking in curved platy blocks.

The contact between the conglomerate and Keewatin as shown in the adit level is very steep to the west. The conglomerate was evidently laid down in an old gulch in the Keewatin surface.

About 14,000 tons of ore have been treated in the mill, which has a capacity of from 35 to 40 tons daily, depending on whether diabase or conglomerate is being crushed.

About 700,000 ounces of silver have been taken from the workings.

Miller Lake O'Brien

This property adjoins the Millerett to the south. The main workings are along the centre line of mining claims R S C 90 and 91.

The rock containing the silver-bearing veins is quartz diabase, which rises as a sill from the east at about 30°. Two hundred feet east of the main workings is an outcropping of Keewatin greenstone which overlies the sill.

The property has been developed from two shafts, No. 1 down 100 feet and No. 2 to the 200-foot level. When visited in October, 1912, the deepest workings were on the 300-foot level, where a 50-foot winze had been sunk to the south of No. 2 shaft from the 250-foot level. The property has been developed on six levels, while the ore which occurs in shoots has been stoped out above the 140-foot level. There is another stope on the 250-foot level.

Development has shown that there are two main vein systems, called No. 1 and No. 2. These have a general strike of N. and S. and are inclined slightly to the west. The No. 2 system has produced nearly all the ore and consequently the development

Fig. 87.—Miller Lake—O'Brien mine.

work has been mostly done there. It contains two series of veins, called hanging wall and foot wall veins respectively.

In each of these systems there are two or more veins which, where the ore shoots occur, have been sufficiently close to mine in one stope. In the ore shoots individual veins are not always productive, but, when one is barren, a parallel one may carry high-grade ore. Both the hanging and foot wall veins have shown ore shoots. Above the 140-foot level ore has been stoped from both the hanging and foot wall veins, while below this level, to the south of the main shaft, the ore has been produced from the foot wall system of veins. Very little ore was found above the 60-foot level. In the workings on the 250-foot level, 125 feet south of the main shaft, a silver-bearing vein was discovered which has an E. and W. strike. This vein had been drifted on for 170 feet, and ore was being stoped above this level.

The great proportion of the silver values are contained within the veins with only a small impregnation of the diabase wall rock. The ore is massive smaltite and silver.

Development has shown the existence of a fault which crosses No. 1 shaft at the

50-foot level and No. 2 shaft at the 140-foot level. This fault dips to the N. and E. A wide calcite vein, which strikes N. 60° E., and is exposed on the surface, has been displaced eight feet by the fault.

Shipments have been made from the property for the past two years.

Mann Mines

The Mann mines are situated on the northwest arm of Gowganda lake. The early discoveries were made in the summer of 1908, causing a rush to the west side of Gowganda lake.

Four shafts have been sunk to moderate depths. Of these, No. 3 on an east and west vein, has been sunk 80 feet, with one drift 165 feet east and another 203 feet west. Two cross-cuts have also been made from the west drift. The early drifting at

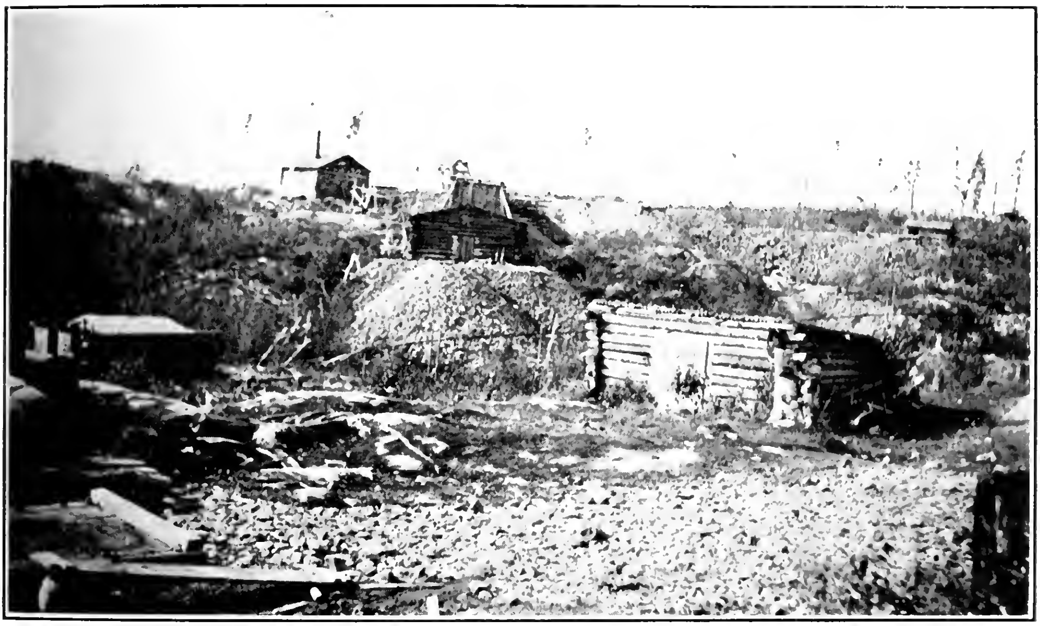

Fig. 88.—No. 3 shaft, Mann mine.

the 80-foot level did not disclose any ore, but further development in the west drift has shown a shoot of high-grade ore immediately south of the old working, which was discovered by following a stringer which showed in the old working. A part of this shoot has been stoped up 15 feet, while two underhand stopes 15 and 20 feet in depth have also been made. This shoot is reported to have been followed for 200 feet. No. 5 shaft has been started on the ridge to the east of that on which is No. 3 shaft. This shaft will be a permanent one, and is fitted with a cage. It was down 56 feet, and will be connected with No. 3 on the 80-foot level and also on the 200-foot level with the winze which is now being sunk in the west drift at No. 3 shaft. Several open cuts have been made. From one of these, west of No. 5 shaft, which is 30 feet long and 30 feet deep, 14 tons of high-grade ore were taken out and shipped. No. 2 shaft has been sunk 60 feet on the continuation of the Boyd-Gordon discovery vein.

The greater number of the veins have a general E. and W. strike, and many of these have been trenched over considerable distances but have not been prospected at depth. A north and south valley, which is sharply defined, may indicate a fault in the diabase, as the veins so far trenched on the two ridges do not correspond in position.

Twenty-five tons of high-grade ore have been taken from the workings. The ore is chiefly massive smaltite and silver.

Two thousand tons of milling rock had accumulated on the dump. Of this an average lot of 20 tons was treated at the Millerett mill, where assays showed a value of 58.8 ounces of silver to the ton.

In one shipment from this property the high-grade ore which averaged about 2,000 ounces silver to the ton also contained $2.00 per ton in gold.

Bartlett Mines

The Bartlett mines, which were closed down for a time, were reopened in 1912. In 1909 two shafts were sunk on the property. No. 1 shaft, which is just south of the power plant, was started on a lens of high-grade silver ore, which occurred in a vein striking nearly E. and W. The lens was followed for 25 feet while the shaft was continued to the 100-foot level. Short drifts were run at the 30-foot level, and at the 100-foot level 290 feet of cross-cutting was done. To the southwest of the shaft there are several open cuts and pits on a vein with strike N. 52° E., which is traceable 350 feet. Some silver ore was taken from an open cut near the shaft. There is an aplite dike which in places has been greatly fractured, with the formation of calcite lenses along parts of it. The calcite contains silver and copper pyrites in parts, while silver in leaf form occurs in the fractured aplite and the diabase wall rock. Some of the diabase is quite decomposed along the vein, and thin leaves and scales of native silver occur 18 inches from the vein.

At No. 2 shaft there are 230 feet of cross-cutting at the 100-foot level. Directly west of the shaft there is an aplite dike, and over a short distance a lens of calcite. A shallow open cut was made at this point, and a few bags of material carrying high values in native silver were extracted from a short shoot. It is expected that the property will be further developed at the 100-foot levels of the two shafts.

South Bay

Active development was in progress on that part of the property which adjoins the southeast claim of the Bartlett mine when visited in October, 1912.

A great amount of surface trenching had been accomplished, and open cuts had been made on some of the veins. Smaltite, niccolite and silver were found at different points. At one place 90 feet south of the shaft some high-grade ore had been taken from a cut about twenty feet in length. The shaft was down 100 feet, and a cross-cut was being run to the south to intersect three E. and W. veins which showed on the surface. A north cross-cut was also being run towards a vein with strike N. 60° W. which crosses from the Bartlett property. A 50-foot shaft had also been sunk just south of the north boundary line, on a vein parallel to the one just mentioned. The material on the dump consists of diabase, with aplite and calcite. Native silver and argentite occur in some of the vein material. Some crystallized epidote showing some silver has been found in this vein.

Columnar structure is quite pronounced in the diabase, and along the joints veins have been formed, suggesting the filling of cooling cracks. Some of the country rock is quite reddish and coarse-grained, and traceable into the dark grey diabase. Much of the reddish rock adjoining the veins is greatly stained with cobalt and nickel bloom.

Discoveries of smaltite, niccolite and silver have been reported in the north part of the township of Donovan and the south part of Charters township, about eleven miles south of Gowganda. These discoveries are in the Nipissing diabase.

The Flanagan lake area, in which the Hudson Bay Mining Company are operating, and the Calcite lake area, where the Powerful mine is being developed, were not visited in 1912.

THE SHINING TREE SILVER AREA

By R. B. Stewart

In accordance with instructions received from the Provincial Geologist, the writer spent part of the season of 1912 examining the area east of Shining Tree lake. Mr. Dowler Freeman served as field assistant during the season.

Discoveries of native silver made in 1909 attracted attention to the area and much development work followed.

Considerable information regarding the geology of the district around Shining Tree lake has already been published. In 1896 Mr. E. M. Burwash* reported on the geology along the Nipissing-Sudbury boundary line, and six years later Dr. Coleman† made an investigation of the iron formation in the vicinity of Shining Tree lake. In 1910 Mr. W. H. Collins‡ made a survey of the area for the Geological Survey Branch of the Department of Mines at Ottawa.

Location and Transportation

The area is situated chiefly in the township of Leonard, in the District of Temiskaming.

The area can be reached from Gowganda, or Ruel on the Canadian Northern railway. A trail from the west side of Gowganda lake runs in a southwesterly direction to Shining Tree lake—a distance of about 15 miles. A rather circuitous canoe route from Gowganda by way of Spawning lake and the Montreal river is also a means of ingress to the area. Probably the best route is from Ruel by way of West Shining Tree lake. The Opickinimika river and lake afford a water course from Ruel to Allin lake, which is about a mile south of West Shining Tree lake. Gasoline launches were in operation on this part of the route during the season. From West Shining Tree lake a canoe route crossing the townships of Asquith and Fawcett, by way of Granite lake and the Montreal river, reaches Shining Tree lake.

The transportation of supplies into the area is a difficult matter, as many portages occur on the canoe routes, and the lack of good transportation facilities has retarded development work. A wagon road from mileage 80 on the C. N. Ry. to West Shining Tree and Shining Tree lakes is under construction.

Topography

The area presents the usual topographical features of northern Ontario. The highest elevation observed is about 175 feet (aneroid) above the general level. The lakes are not as numerous as in many parts of northern Ontario. Shining Tree lake is the largest and is about four miles long and over a mile across in the widest part.

Geology

The Keewatin formation extends over part of the area. It is represented chiefly by greenstones showing marked ellipsoidal structure and by altered diabases or basalts. A narrow belt of the iron formation occurs east of Fournier lake, which lies about the centre of the township of Leonard. The trend of the outcrop is a little west of north. Another outcrop, showing bright red jasper, occurs in the southwest part of Tyrrell township. The latter exposure is probably a continuation of the one at Fournier lake, but later sedimentary rocks separate the two areas.

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*Sixth Report of Bureau of Mines, 1896, p. 173.
†Report of Bureau of Mines, 1901, p. 181.
‡Summary Report, Geological Survey, 1910, p. 196.

The Cobalt series is represented by conglomerate, quartzite and banded slate. These rocks cover much of the territory examined. The conglomerate contains well rounded boulders of granite, greenstones and other rocks of the older formation. The quartzite or arkose is similar to that of the Elk lake area. The banded slate lies practically horizontal, but in several places it was observed that it dips slightly toward the overlying diabase.

A sill of Nipissing diabase covers a portion of the area, and overlies the Keewatin and the Cobalt series. The diabase is rather coarse in the grain and varies from a dark colored rock of gabbroid texture to light colored acid types. These acid phases occur as aplite dikes, and in small areas where the chief rock-forming mineral is a reddish feldspar.

Fig. 89.—Specimen 6½ inches in width of Agglomerate, showing amygdaloidal structure, east side of Spider lake, Leonard township.

Dikes of olivine diabase were observed intruding all the formations in the area except the Nipissing diabase. Phenocrysts of feldspar, an inch or more across, can be found occasionally in the olivine diabase.

Besides the rocks described above other types occur whose place in the geological succession was not definitely determined. Agglomerates are exposed on the east side of Shining Tree lake at its northern end, and on the east side of Spider lake. In the latter place the agglomerate consists chiefly of angular fragments of a bluish grey rock cemented with a rather fine-grained darker material. Many of the fragments have a finely vesicular structure but occasionally some contain larger amygdules—half an inch in length or more—which are filled with quartz.

The agglomerate exposed on the east side of Shining Tree lake presents a different appearance than the one described. This rock is made up of fragments, an inch or more across, of a pink colored, finely vesicular rock set in a fine-grained, green colored matrix. The vesicular cavities are filled chiefly with calcite, but some contain quartz.

A sedimentary series, consisting of a fine-grained slate rock, interbanded with a slightly coarser grained and more silicious rock is exposed in several places on the shore of Black lake, and on the islands in the lake where it can be observed very distinctly. Here the strike of these interbanded rocks is a little west of north and their dip is almost 90° to the west. The remnants of several folds of interbanded rocks, strikingly similar to those on the islands in Black lake, occur on the east side of Herron lake and appear to be overlain by the flat lying banded slate of the Cobalt series. It appears from their relation to the Cobalt series and from their disturbed condition that these folded and steeply dipping fragmental rocks belong to the Temiskaming series.

In the vicinity of Black and Spider lakes a grey-colored, cherty-looking porphyritic rock is exposed in several places. The phenocrysts are usually feldspar and quartz. Later disturbances have crushed and brecciated the porphyry in places to such an extent that it resembles a fragmental rock.

The Pleistocene deposits effectually conceal the underlying rocks in several parts

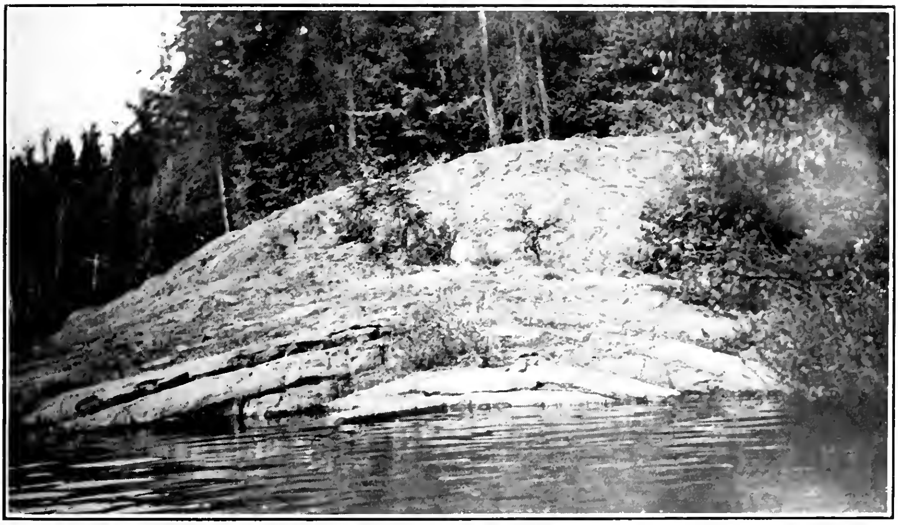

Fig. 90.—Folded sedimentary rocks, east side of Herron lake, Leonard township.

of the area, but in other places a thin sheet of boulder till forms the superficial material. Esker-like ridges of sand and gravel occur in several places, and sand deposits cover stretches of considerable size. Slight stratification was observed in the sand about half a mile southwest of Fournier lake.

Character of the Veins

The silver-bearing veins occur in the Nipissing diabase, although similar veins have been located in the agglomerate and conglomerate. The veins occupy distinct vertical fissures that have a general strike of north thirty to forty degrees east (magnetic). Some east and west fractures occur in the diabase, but these are generally mere cracks.

Numerous veins occur on many of the properties, but the majority of them will average only a few inches in width. Large veins, four to eight feet wide in places and extending across two or three adjoining claims, are a rather marked feature of the area.

Calcite and quartz constitute the chief vein filling materials. The quartz is found frequently in a thin layer on the walls, and the calcite, usually of a white and coarsely

crystalline variety, especially in the larger veins, fills the remainder of the fissure. The weathering of the calcite has formed cavities many feet in depth in several of the veins, and in some places practically all the calcite has been dissolved out to a depth of several feet for some distance along the vein. Copper pyrites, smaltite, niccolite, native bismuth, galena, and cobalt bloom are the associated minerals in the veins.

Native silver was seen on five claims. The quantity in every case was small, and the silver-bearing veins are narrow. The silver occurs in the calcite and quartz. It is also found in the black muck-like material that collects in the weathered-out cavities in the calcite. No silver, as far as the writer could ascertain, has been found in the large veins, although no evidence was obtained to show that the large ones were not contemporaneous with the smaller veins.

Mining Locations

The Seville Exploration Syndicate

The holdings of this company comprise a group of eleven claims, which are situated south and west of Fournier lake. Silver was first found in the area on this property in May, 1909. Considerable surface work has been done on the claims. Many well-

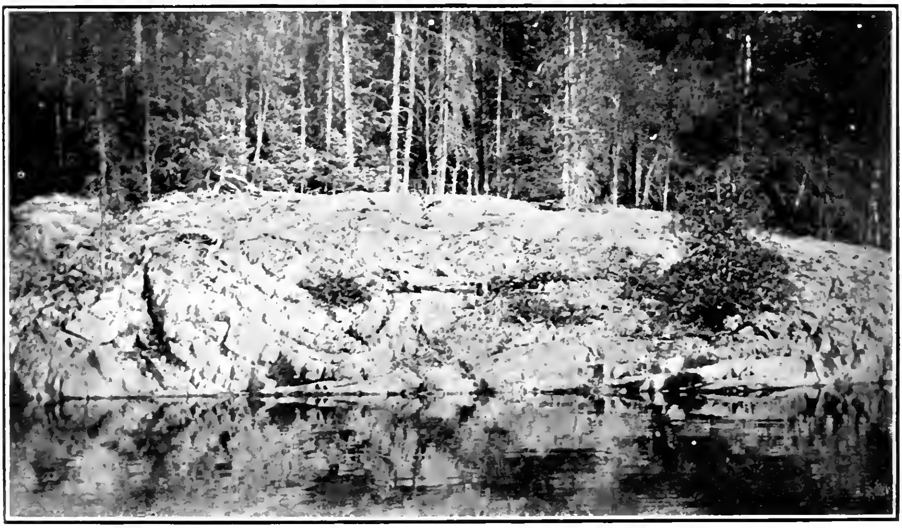

Fig. 91.—Folded sedimentary rocks, east side of Herron lake, Leonard township.

defined veins occur in several places on the property. Much bloom, with smaltite, copper pyrites, and a small amount of bismuth was observed in several of the veins. No silver was found in place, but small specks were found in pieces of vein matter that had been taken out of one of the veins. The trenches are filling up again to a certain extent, so that small isolated showings of silver could easily escape detection. All the veins that were visited are in the diabase. No work was in progress on this property during the season.

Turnbull's Claims

These claims are situated immediately west of those of the Seville Exploration Syndicate. The country rock is diabase. On one of the claims a large calcite vein has been uncovered for about three chains. This vein is 3 or 4 feet wide in places. Just west of the large vein another one occurs that will average probably 8 or 10 inches in width for a distance of about three claims. The two veins have a strike of about north 30 degrees east magnetic. In the vicinity of the large veins many small stringers occur, one of which carries cobalt bloom.

E. L. Greave's Claims

This group of three claims is located just south of Turnbull's. Surface work was being carried on when the writer visited the property. Three veins 3 to 6 inches wide occur in the diabase on the most southerly claim. Small amounts of silver were seen in the three veins. The gangue material is quartz and calcite, with small quantities of copper pyrites, galena and smaltite. Surface work on the most northerly claim has exposed two veins of quartz and calcite associated with aplitic material, but no silver had been discovered.

Caswell-Eplett Claims

These claims (W D 1145 and 1146) are located a little west of Fournier lake and immediately north of the claims of the Seville Exploration Syndicate. The formation is chiefly diabase, but the contact between the diabase and the Cobalt series occurs on W D 1145. Quite extensive surface work has exposed many veins on W D 1146. Cobalt bloom occurs in several of the veins. Small flakes of native silver were found in the black muck-like material in a small vein just west of the shaft.

The most extensive underground work in the area has been done on W D 1146. Mining operations were not in progress when the writer was on the property, but some information regarding the underground work was obtained from Mr. Grant Caswell. A vertical shaft was sunk 100 feet on a vein that showed silver at the surface. A cross-cut was run 100 feet east and the same distance west from the shaft. On the east side a calcite vein eighteen inches wide, and a vein of niccolite 4 to 6 inches wide were crossed. A calcite vein was found on the west side of the shaft.

The plant consists of a 20-h.p. upright boiler, a 5 x 5 hoist, three pumps and a Rand drill.

It was intended to resume work during the winter.

Archibald's Claim

This claim lies immediately east of the group of claims of the Seville Exploration Syndicate. Part of the property is heavily overburdened with sand that shows slight stratification. The rock formation is diabase. Surface work has exposed three veins from 3 to 6 inches wide and having a general north-south strike. Many smaller stringers and fissures occur in the vicinity of these veins. A small quantity of native silver was observed in one of the larger veins. Quartz and calcite are the chief vein filling materials. Small amounts of galena, copper pyrites and cobalt bloom are present.

Neeland's Claim

This claim (H S 448) lies just north of W D 1146. Considerable surface work has exposed six or seven veins a few inches in width and with a strike of north to north 60° east. The formation is diabase. Quartz and calcite are the chief vein filling materials, but copper pyrites and cobalt bloom are present, and in one vein niccolite one to two inches wide occurs. No silver was seen on this property, but the writer was informed that good samples of native silver had been taken from one of the veins.

Nellie Lake Syndicate

This company have a group of 19 surveyed claims located in the vicinity of Nellie lake. The chief underlying rock is diabase, but some claims in the group are located on Keewatin. Extensive surface work has been done on several of the claims and many veins have been exposed, of which some are very large. During the season a shaft 34 feet deep was sunk on a large vein that occurs on T C 730 and T C 731. This vein has been uncovered for a distance of about 8 chains, and is 5 to 6 feet wide in places. Its average width is probably about two feet. The gangue material is calcite, but cobalt bloom, smaltite, niccolite, and bismuth in small quantities are present. The

vein has almost vertical dip and strikes, in a general way, about north 25° east. No silver was seen in this vein.

Several other shafts and test pits, varying from 20 to 60 feet in depth, have been sunk on promising looking veins on these claims.

The development work during the summer was under the management of Mr. Mullan.

The McIntosh Mines Ltd.

This company's claims are located west of Spider lake, in Leonard township.

The prevailing formation is diabase, but areas of the underlying conglomerate and banded slate occur on several of the claims.

Just east of Spider lake a vein 6 to 8 inches wide has been uncovered for several chains. The gangue is quartz and calcite, with considerable copper pyrites and cobalt bloom. This vein dips at a high angle to the west. The surrounding rock has been

Fig. 92.—Camps of the McIntosh Mines, Limited, at Spider lake, Leonard township.

severely shattered and many smaller veins occur in the immediate vicinity. A shaft 65 feet deep has been put down on this vein.

Just east of the vein described above, another vein has been located. This is a very long vein, that runs in a southwesterly direction on to B G 264, crosses the northwest corner of Dalton Thomas' claim and appears in B G 252 for several chains. This vein varies in width from a mere crack to 5 feet in width. It dips in places at a high angle to the west. Calcite and quartz are the chief vein filling materials, but copper pyrites and cobalt bloom are abundant. Where the vein crosses Dalton Thomas' claim niccolite one inch wide occurs.

Camps have been erected on the property and a 12-h.p. boiler and hoist have been installed at the shaft. No work was in progress during the season.

The Darby Claims

These claims are located at Horse Shoe lake. The formation is diabase. Surface work has uncovered several veins that have the general characteristics of the veins of the area.

L. O. Hedlund's Claims

This group of three claims is located in the southeastern portion of Leonard. The formation is diabase overlying the Cobalt series. A vein striking about northeast has been uncovered for several chains. A test pit has been put down on this vein, which is about a foot wide at the pit. Calcite and quartz are the chief vein materials. Cobalt bloom, small quantities of smaltite and copper pyrites are present.

The Exploration Syndicate of Ontario

This company control a very large number of claims in the area. At Shining Tree lake a number of claims have been located on the west side. South of the lake a group of twenty-eight claims have been staked on several areas of diabase that occur

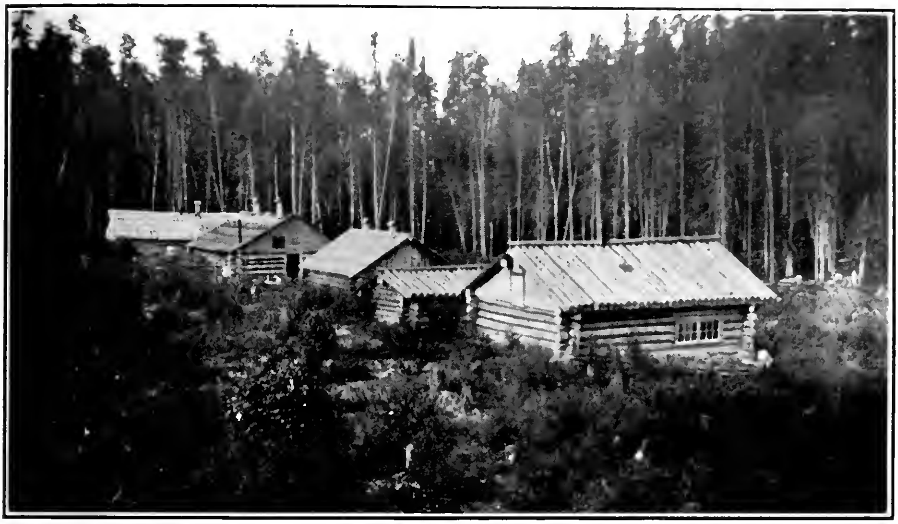

Fig. 93.—Camps of the Exploration Syndicate of Ontario at Treacy lake, North Williams township.

in that locality. No veins were seen on this group, but the writer was informed by Mr. Smith, formerly engineer for the company, that a strong vein of smaltite occurs on one of these claims.

This company own a group of sixteen claims at Treacy lake, in the southwest portion of the township of North Williams. Considerable work has been done here. On T C 338 a shaft 7½ by 9 feet and 50 feet deep has been put down. A cross-cut runs 48 feet to the southwest. The surface work near the shaft has exposed several narrow veins in the diabase. Native silver was seen in two of these veins.

Comfortable camps have been built on this property and a 12-h.p. boiler and hoist have been installed. During the season a small gang was engaged in surface work.

FLORENCE LAKE, SHINING TREE AND ROSIE CREEK AREAS

By W. H. Collins

"Florence lake, at the head waters of Lady Evelyn river, lying 38 miles west of Latchford, is most easily reached from Temagami or Latchford station on the Temiskaming and Northern Ontario railway. . . . Florence lake is an irregular body of beautifully clear water, six miles in length, lying 1,190 feet above sea level. . . . The geology of the district is simple; a quartzite of Huronian age traversed by sills and dikes of diabase covers most of the area. The quartzite is a greyish or greenish-white rock, usually feldspathic, which frequently grades into arkose or becomes finely conglomeratic. The bedding planes are indistinct, so that the rock has a massive appearance, and the dip and strike are seldom determinable. A few reliable observations of the dip indicate a gently undulating attitude with a general southeasterly inclination. The diabase is quite similar to that found in the Montreal River district. The diabase exhibits the usual fine-grained and gabbroid types and occasionally an acid syenite phase. It is cut by aplite dikes and quartz calcite veins. The quartz calcite veins show the same structure as those of the Montreal River district, but were observed to carry only chalcopyrite, except at one point near the middle of Florence lake, where a trace of cobalt bloom was perceived."*

"Calcite veins of the same type as the silver-cobalt veins of Gowganda and Cobalt districts are associated with remnants of quartz-diabase sills that occur at intervals throughout the district. But with few exceptions they are too poorly mineralized to be economically important, and are interesting only in showing how persistently silver-cobalt deposits accompany the diabase. Most of the discoveries were made in 1909, since which time prospecting for silver in this district has steadily declined, and has now almost ceased except near Shining Tree lake.

Shining Tree Area

"Shining Tree mineralized area lies east of Shining Tree lake in Leonard township. The known veins are confined to about four square miles of a diabase sill that overlies Keewatin and Huronian rocks. A considerable number occupy wide and persistent fissures frequently in parallel N.-S. series, and a few contain silver.

Archibald Claim

"The diabase underlying the property is traversed by a group of three parallel N.-S. veins, the outermost of which are 80 feet apart. They vary in width from one to three inches, and are stripped for distances varying from 60 to 160 feet in length. Small flakes of silver can be seen at two points along the most easterly one, and a little specularite, chalcopyrite and cobalt bloom occur in all three.

Caswell Claims

"A similar group of parallel but less regular veins striking N. 15° E. intersect the diabase on this property. When visited in August, a vertical shaft had been sunk 92 feet beside one of the veins, at the surface of which a little native silver had been found.

Rosie Creek Area

"Rosie Creek area includes adjacent portions of Unwin and Browning townships on either side of Rosie creek, a small tributary of Wanapitei river. It consists of a flat sand plain, above which rise occasional hills of Lorrain quartzite or of diabase. The veins that have been found, though of good size, are crooked and contain a somewhat typical mineral assemblage. Silver has not been recorded except in traces, determined by assays. Smaltite and cobalt bloom occur, but chalcopyrite and galena are more common, and slender prisms of stibnite are present in one vein."†

*Florence Lake and Montreal River Districts, W. H. Collins, Summary Report, Geol. Survey, 1909, p. 168.

†Geology of Onaping sheet, Ontario, portion of map-area between West Shining Tree and Onaping Lakes, W. H. Collins, Summary Report of the Geol. Surv. Branch of the Department of Mines, Canada, 1911.

TOWNSHIP OF LANGMUIR, PORCUPINE AREA

By A. G. Burrows

"The property of the Premier Langmuir Mining Company is situated in the township of Langmuir, along the south boundary and immediately west of Night Hawk river. On the property is a prominent ridge of Archean rock, which rises about 125 feet from the surrounding drift. The rock enclosing the veins is principally Keewatin greenstone schist. To the south there is intrusive reddish syenite in some volume. Narrow dikes of syenite cut the greenstone, and both rocks are cut by veins of barite. These veins occur along the northeasterly slope of the Archean hill. The

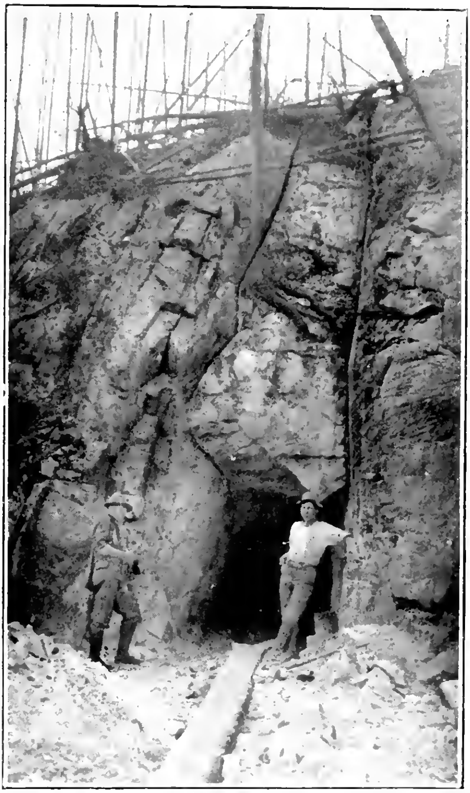

Fig. 94.—Barite vein on property of Premier Langmuir Mining Co., Langmuir township.

main vein has been traced about 1,000 feet in a direction somewhat south of east, while a branch vein has been followed about 350 feet with an E. and W. strike. The main vein would average from two to three feet in width, and at one place has a width of eight feet. A tunnel has been driven on the main vein at its westerly end a distance of 100 feet. The vein matter shows barite, with sparingly disseminated galena. Much of the barite is very pure in appearance, but portions of it contain calcite. About 500 feet east of the tunnel a shaft has been started on the branch vein, where it shows a width of 50 inches. Towards the south wall of this vein, where a cut had been made for the shaft, there are a few streaks or bunches of dark minerals. These consist principally of black or brown zincblende and galena, and in addition there are scattered flakes of native silver and argentite. Iron and copper pyrites also occur sparingly. It was noted in the pit on the east vein that the barite was cut by some minute veinlets of quartz, along which most of the sulphides occur. This would

suggest that the sulphides, along with the silver, came in with the quartz. Fluorite has been obtained in some narrow cross veinlets from the larger vein. The barite veins have well-defined walls, and the filling breaks freely from the wall rock. A quantity of commercial barite could be obtained from these veins.

"No smaltite or bloom was seen in the vein matter, but bloom was obtained about one mile to the west. Some small areas of diabase occur in the vicinity, but not immediately near the Keewatin area in which the veins are found."*

OTTER TOWNSHIP†

Occurrence of Cobaltite and Native Bismuth

By A. G. Burrows

The township of Otter is seventeen miles north of the town of Thessalon, which is on the north shore of lake Huron.

On the Kerr claim, S.E. ¼ of S. ½ lot 1, con. 4, there are two quartz veins which strike N. 65° W. The northerly vein, which at one point has a width of 12 feet, contains copper pyrites and specular iron ore, in addition to the quartz and calcite. The southerly vein has been stripped over a distance of 230 feet, and at one place a pit has been sunk 13 feet. In the pit the vein is 7 feet wide, consisting for the most part of quartz, or quartz and diabase in a reticulated structure. Calcite occurs in lesser amount and cobaltite and native bismuth have been found in small masses. To the east and west of the pit the vein is much narrower.

On the adjoining claim to the east there is a quartz vein with a similar strike averaging a foot in width. It has a decided comb structure, some of the quartz crystals being an inch in diameter. Calcite and occasionally cobaltite and native bismuth have been deposited between the quartz layers, and thin sheets of bismuth sometimes occur on the smooth faces of the quartz crystals.

One sample from the Kerr claim, consisting mostly of bismuth, gave on assay: gold, .03 oz.; silver, 15.9 oz.; bismuth, 59.5 per cent.; cobalt, trace. A sample of massive cobaltite gave on assay no gold or silver.

The rock enclosing the veins is quartz diabase. It occurs over a number of claims and shows differentiation to acid phases.

Under the microscope a sample of dark grey diabase shows the feldspar greatly altered to saussurite, while the pyroxene is almost wholly changed to green hornblende, uralite. Quartz is abundant in grains and in micrographic intergrowth with feldspar.

An acid differentiation of the diabase occurs about one-half mile to the south. It contains greenish laths of plagioclase and also a reddish feldspar, which is intergrown with quartz, giving a red color to the rock. The dark minerals are green and brown hornblende, and chlorite.

Ridges of a coarse boulder conglomerate and a reddish granite were observed near the diabase.

The diabase evidently occurs as a sill, and may correspond to the Nipissing diabase at Cobalt.

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*Twenty-first Report, Bur. of Mines, 1912, Part I., pp. 248-249.

†Otter township lies north of the town of Thessalon, about 190 miles southwest of Cobalt.

CHAPTER III

1. LAKE SUPERIOR SILVER DEPOSITS

The Silver Islet mine and the silver mines on the main shore to the southwestward of Port Arthur are well known to students of ore deposits. In richness of silver they resemble those of Cobalt station, but they contain a much lower percentage of cobalt, nickel and arsenic. Cobalt bloom and nickel bloom, together with arsenides and other compounds, were, however, found in these lake Superior deposits with the silver. A similar assemblage of minerals, but in a much smaller quantity, was briefly described years ago as occurring on Michipicoten island.* It is well known that native silver occurs in association with native copper in the great copper mines of Michigan on the south shore of Superior. It would seem then that native silver is not a very rare mineral in the region between the Quebec boundary and the north and south shores of Lake Superior. Port Arthur, however, lies about 500 miles west of Cobalt, and in the intervening area no deposits of the metal have been found. There is ground for hope that deposits will be discovered when this area is explored. Little is known about much of it at the present time.

The Port Arthur Mines

Much has been written on the silver mines in the area adjacent to Port Arthur. This literature has been summarized and many additional details given in an important report written by Mr. E. D. Ingall of the Canadian Geological Survey.† None of these mines are now working.

It will be seen from the following notes, condensed from Mr. Ingall's report, that these Port Arthur deposits in many respects, especially in the facts that they occupy for the most part vertical fissures which cut slightly inclined pre-Cambrian beds, and in their mineral contents, resemble the silver-cobalt deposits in the vicinity of lake Temiskaming. The chief difference between the two as regards their mineral contents is that the Port Arthur deposits contain a higher percentage of gangue material, the ore usually occurring in bunches or pockets, and the percentage of silver is always much higher than that of the associated nickel and cobalt which generally occur in small quantities or are entirely absent in some of the deposits. Some of the veins in the vicinity of lake Temiskaming on the other hand contain a much smaller amount of gangue, and the percentage of cobalt, nickel and arsenic is often higher than that of silver. One of these veins, that in the north-west corner of R L 404, described on a preceding page, consisted as exposed at the surface of about 14 inches of solid smaltite together with niccolite. There was little gangue in this ore. The Cobalt station deposits, as previously stated, resemble, among veins which have been worked in the world, more closely those of Joachimsthal in Austria and Annaberg in Saxony than any others.

It is interesting to know, however, that nickel did occur in the Silver Islet mine, at least, in economic quantities. The first ores of this metal of this Province, which is now such an important producer of the metal, were those of the Silver Islet mine. Mr. W. M. Courtis, in a paper read before the American Institute of Mining Engineers, October, 1873, in speaking of the smelting works at Wyandotte, says that the matte was treated to save the nickel and that the silver was extracted from the marketable nickel speiss.

Ingall says the vein-filling minerals consist of quartz, barite, calcite and fluorite. In these occur various metallic minerals, viz.: blende, galena, pyrites of various species and occasionally some sulphurets of copper, whilst the silver occurs as argentite and in the native state, the former being the more common. At places the veins carry a dark green, probably chloritic, material, which on some surfaces has a bright waxy

* "Geology of Canada," 1863, pages 506 and 703.

† "Report on Mines and Mining on Lake Superior," by E. D. Ingall, Part H, "Annual Report of the Geological Survey of Canada, 1887," 124 pages, with colored geological map.

See also "Silver in Thunder Bay District," by N. L. Bowen, Part 1, "20th Report Ontario Bureau of Mines, 1911," pages 119 to 132, with colored geological map, one mile to one inch.

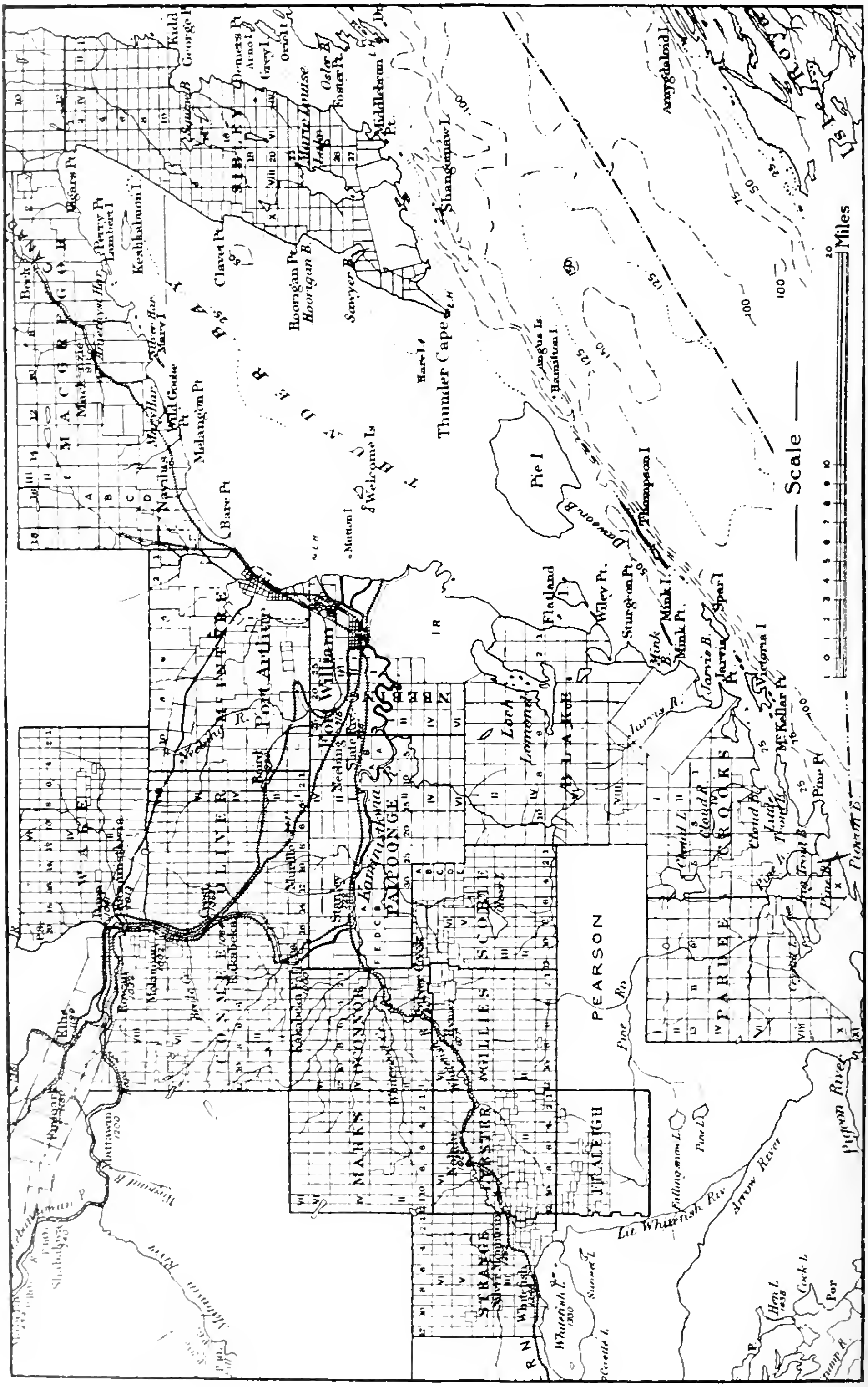


Fig. 95.—Key plan, showing location of silver areas, north shore of Lake Superior.

lustre, whilst occasionally a soft, greasy, talcose material, probably saponite, accompanies the ore, notably at the Beaver mine, and to a lesser extent at one or two other places. Carbon in various forms has also been found here and there, whilst in some of the vugs in the veins which have been found near the surface, stiff clay and ochreous material have sometimes been obtained along with nuggets of argentite, the former, however, having evidently been washed in from the surface and thus imbedded the silver minerals already existing in the vugs.

The same writer further states: "These, then, are the mineral constituents of these veins, but the Silver Islet vein forms somewhat of an exception in that it carried, besides these, various arsenical and antimonial ores of silver with compounds of nickel and cobalt and other metallic minerals which have so far not been found in the rest of the veins (?). Other salient features were the pink and cream-colored dolomitic spar which so frequently formed a characteristic and prominent constituent of the

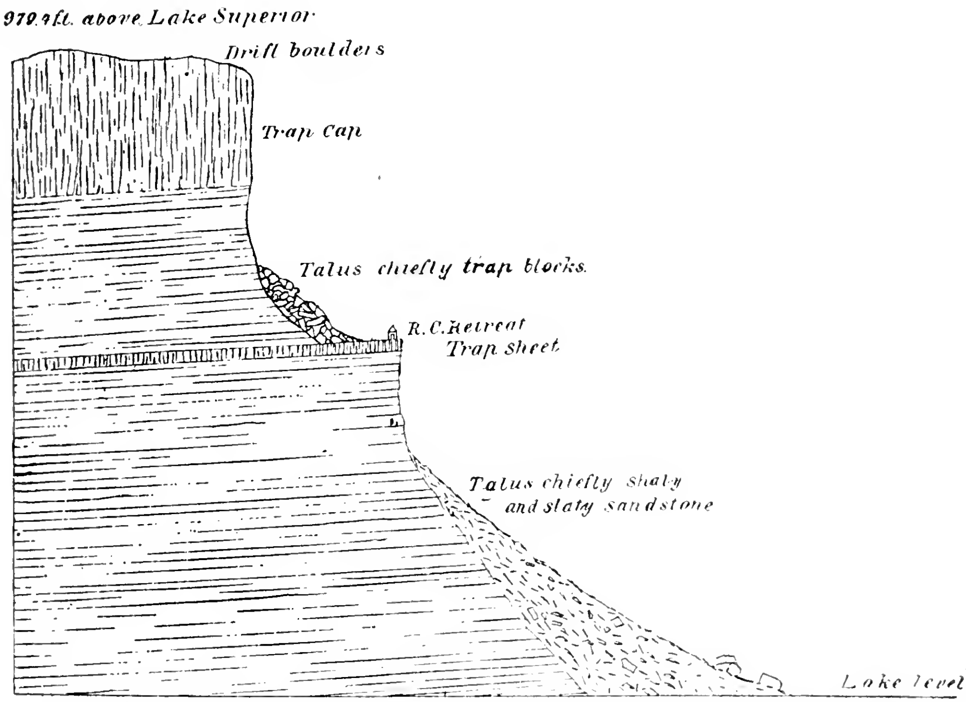


Fig. 96.—Section through Mt. McKay, near Fort William, Ont. The trap here bears a similar relationship to the slaty series to that which it has in the Cobalt area. Some silver veins in the Port Arthur area cut both the trap and slate. (After Dr. A. C. Lawson.)

gangue of the rich ore, and the predominance of native silver in the rich parts, whereas in the rest of the veins, though this form of silver occurs in considerable quantity in places, yet argentite seems to be the form in which it it generally found."

"Again, it is interesting to know that both the mineral waters and the inflammable gas that were met with in opening up the Silver Islet mine have also been encountered at other points in the district. At the Rabbit Mountain mine in one of the lower levels I saw water running over the breast of the drift which gave off a faint odor of sulphuretted hydrogen and was depositing a while flocculent material, whilst both at this place and at the Beaver mine I was informed that small quantities of inflammable gas had been met with."

These veins, like those of Temiskaming, frequently present a brecciated appearance, angular fragments of rock being enclosed in the vein material.

Ingall found the distribution of the silver minerals in the veins very irregular, the

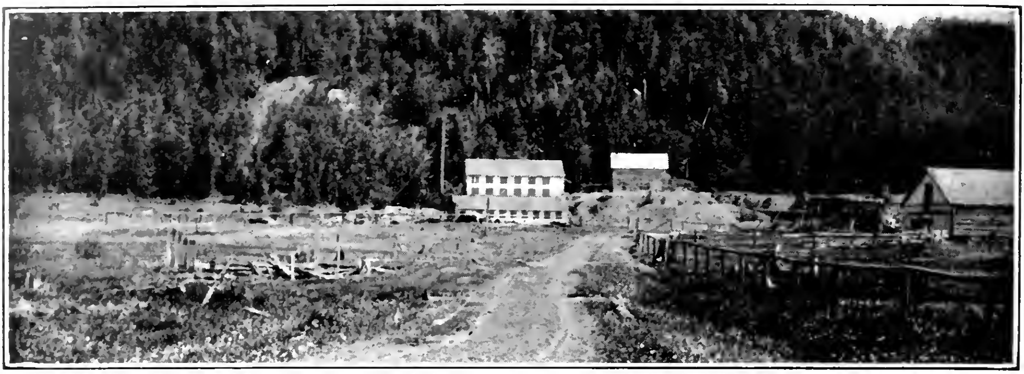


Fig. 97.—Mill at the Beaver mine.

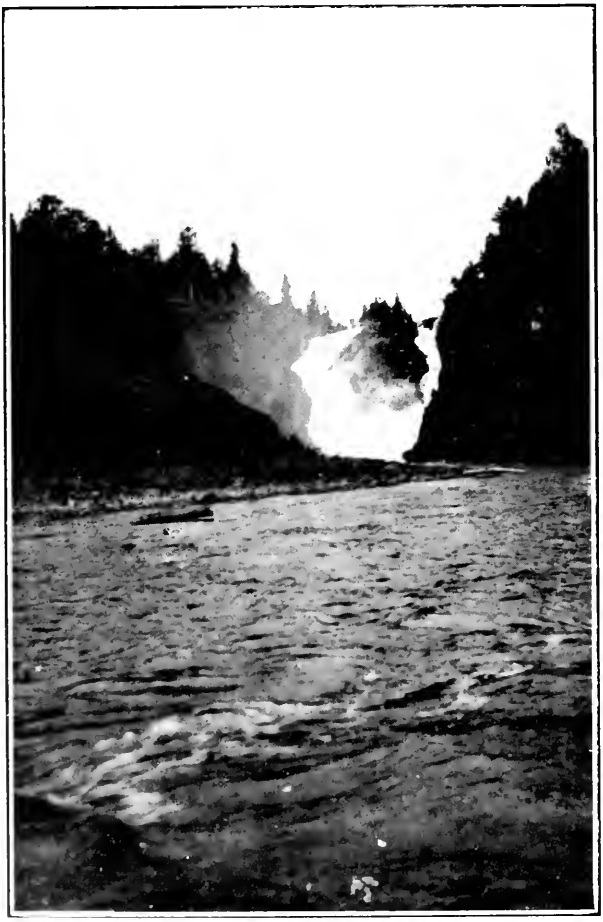


Fig. 98. Kakabeka Falls and Gorge in Animikie strata.

rich ore generally occurring in detached bodies of varying dimensions surrounding very poor or quite barren areas of the vein.

As regards the metallic minerals, it was observed by Ingall that the blende comes first in importance, being the most plentiful. This mineral is practically absent in the Temiskaming deposits. The galena does not play such an important part, Ingall says, as the blende. Pyrite is found to a lesser extent than the two last mentioned minerals. Both pyrite and galena are likewise rarely met with in the Temiskaming veins. Marcasite and pyrrhotite are found in the Port Arthur veins, but copper compounds represented by chalcopyrite and copper-glance are rare. Through the blende, galena and pyrite, or through the gangue minerals, are distributed the argentite and native silver. It is said that, with the exception of Silver Islet, the native silver is more characteristic of the ore bodies near the surface and is replaced by argentite in depth. The likelihood of blende, galena and pyrite carrying silver is asserted to be in the order in which they are here named. Silver was found in but few specimens. Traces of gold were obtained in these minerals, in a few instances.

The calcite is said to be apparently older than the quartz, and there is also some secondary calcite. The silver minerals seem to be due to a later infiltration of silver-bearing waters subsequent to the deposition of the gangue minerals.

Regarding the source of the silver minerals Ingall does not offer any definite theory. He says some writers have thought them to be connected with the trap eruption, the silver being brought up by thermal waters accompanying these intrusions. He points out, however, that these fissures intersect and dislocate the trap sheets and dikes. He adds that the fact remains that all the ore bodies occur near or within a reasonable distance of trap in some form, either in dikes or in sheets. This suggested the idea to him that the silver may be derived by decomposition of some of the mineral constituents of the trap carrying minute quantities of silver. On decomposition, waters infiltrating downwards through the fissures might have deposited their silver contents in them. He thinks that the various forms of carbon present in the sedimentary rocks may have had some influence in effecting this precipitation.

Silver Islet Mine

This deposit, which occurs on an islet, less than 80 feet in diameter, about a mile out in the lake off Thunder Cape, was discovered in the summer of 1868. It is the most famous silver mine worked in Canada, till the discovery of the Cobalt camp, the silver produced from it amounting in value to $3,250,000. The vein on this islet intersects what is called a chloritic diorite dike in its course through the sedimentary beds of the Animikie. The producing part of the vein was practically confined to that portion between the walls formed of the dike material.

We shall not attempt to give a fuller account of this vein here, but shall refer the reader who wishes more details to Mr. Ingall's interesting report. It will be well, however, for the purpose of comparison, to give a list of the minerals found in this vein. Among these are the gangue minerals, calcite, quartz and dolomite, the latter varying in color from cream to pink according to the amount of manganese contained. A variety known as rhodochrosite is said to have been found. The metallic minerals are native silver, argentite, galena, blende, copper and iron pyrites with marcasite, tetrahedrite, domeykite, niccolite and cobalt bloom, together with a mineral known as macfarlanite containing arsenic, cobalt, nickel and silver. Two new minerals are said to have been found in the ore; these were called huntilite and animikite, which with macfarlanite, according to one writer, were the principal producing silver ores of the mine. There were also found, annabergite, antimonial silver and cerargyrite, the latter "where the rock has been decomposed." Graphite is said to occur in quantity. A curious feature of the vein was the combustible gas met with in large quantities in the workings and the mineral water which carried considerable amounts of chloride of sodium and other metals. Two very rich bunches or bonanzas of ore were found in the vein. One of these was completely worked out in 1874, yielding over $2,000,000. The shape of this

bonanza was that of an irregular pear, and throughout its extent in both veins, that is the main and branch vein, it was accompanied by a strong impregnation of graphite. The bulk of this bonanza was arborescent silver, more or less mixed with macfarlanite, a rich ore of silver carrying 78 per cent. of that metal along with arsenic, cobalt and nickel. Its physical structure resembles niccolite.

In drifting south on the third level in 1878, strong impregnations of graphite were met on the hanging wall which were soon followed by the second bonanza. This deposit of silver was remarkable for its great width, five feet solid across the breast, and the occurrence in great quantity of the two previously unknown compounds of silver, animikite and huntilite. The shape of this bonanza was that of an inverted cone with a base of about 50 feet in the third level, with the apex down as far as the fifth level. This deposit was phenomenal in its structure, and a winze in the middle of the deposit to the fourth level, 60 feet, was sunk literally through native silver, the metal standing out boldly from the four walls of the winze. In the breast of the drift it stood out in

Fig. 99—Silver Islet, with mine buildings, in the distance.

great arborescent masses in the shape of hooks and spikes, in gnarled, drawn out and twisted bunches, followed by arborescent silver with intercalated bands of animikite and huntilite. The width of the vein was over 10 feet, and the entire deposit, including the stamp rock, yielded about 800,000 oz. of silver.

While the vein continued to the greatest depth reached in the shaft, over 1,200 feet, little ore was met with in the lower workings, no silver being obtained from great stretches of vein material.

To give an idea of the richness of the ore produced from this vein in the earlier part of its history, it may be said that the 1,154,537 lbs. of ore produced up to the season of 1872 averaged $1,322.44 per ton. Silver then sold, however, at more than twice its present price.

Ores of other Lake Superior Mines

In order to show the character of the minerals found in other deposits of the Port Arthur area we may cite the following examples given in Ingall's report. Argentiferous blende was the chief silver-bearing ore of the vein on McKellar's island. On Spar island the metallic minerals were copper glance, copper pyrites, zinc blende and a little argentite (Fig. 104). Prince's mine, the oldest mine on the Canadian shore of the lake, having been worked in 1846 or 1847, appears to have been regarded more in the light

of a copper than of a silver-bearing vein. It contained native silver disseminated in thin laminæ through the calcareous spar and blende. Argentite was also found in this vein, and the calcareous spar was stained with blue and green carbonates of copper and with arseniate of cobalt. The vein on Pie island contained blende, galena and iron pyrites.

The veins so far mentioned belong to what Ingall calls the Coast group. In the second or Port Arthur group he says the silver veins may be considered in two divisions: (1) Those which occur in the Animikie rocks; (2) Those occurring in the Archean area to the north of the former. Most of the veins are contained in the first division. A number of veins are described by Mr. Ingall under this heading. The Shuniah or Duncan mine is interesting owing to the fact that the vein here passes downward from the Animikie rocks into the underlying Archean, which consists of what are called diorite, syenite, felsite, etc. It is said that no silver was found in that part of the vein

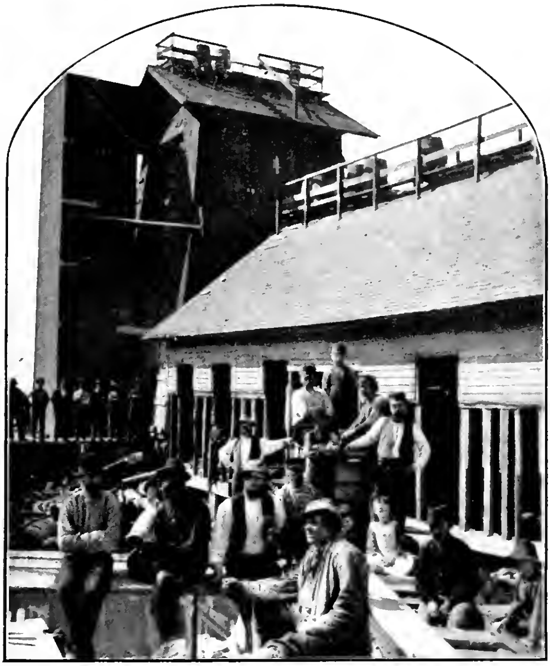


Fig. 100.—Silver Islet, main shaft of mine.

contained within Archean walls. At the 3A mine the gangue was mostly quartz with a little calcite, through which were distributed ores of iron, copper, lead, zinc, nickel and silver, with some cobalt and gold as shown by the assays. The silver was found native and combined with sulphur and nickel. One sample of the ore is said to have assayed 1.4 per cent. of cobalt and 25 per cent. of nickel. This vein was in what Ingall called the Archean or Huronian, the rocks being gray dolomitic schists associated with dark-green compact diorite, whilst dark grayish red, felsitic syenite occurs a short distance to the south. Near 3A mine was a vein containing two feet of milky quartz, which is interesting on account of the fact that it was said to carry native bismuth, the only mention made of this mineral, which occurs in most of the Temiskaming deposits. The Emmons' mine, on lot A in the township of McIntyre, is said to have contained mispickel, another mineral which seems to be rare in the vicinity of Port Arthur.

Rabbit Mountain Group

This group of mines, which was discovered a number of years after the Silver Islet and other veins of the Coast group, is said by Ingall to present somewhat different conditions of occurrence from those just mentioned. The veins are all in the Upper argillaceous division of the Animikie with its associated trap sheets. The ore of the Rabbit Mountain mine consists of native silver and argentite with other minerals. A special feature of the Porcupine mine, one of this group, is that it carries witherite, the carbonate of barium. In the Beaver mine there is the occurrence of saponite already mentioned.

The Silver Mountain group presents features similar to those of the group just referred to. The veinstones are calcite, barite and quartz with fluorite. The enclosing rock is argillite. The metallic minerals are represented by blende, both light and dark-colored, galena and iron pyrites, with occasionally a little copper pyrites, the silver occurring both native and as argentite.

Fig. 101—A Miner of Silver Islet.

Woodside's vein differs from the others in the area in that it occurs in the Archean granitic and gneissic rocks underlying the Animikie. The vein in its nature and contents is very similar to the rest, and carries blende, galena and pyrites distributed through the usual gangue in moderate profusion.

There is also what is called the Whitefish Lake group. The veins here mostly occur in the lower silicious rocks of the Animikie. They have much the same contents as the preceding ones.

The map, page 198, shows the townships along the Port Arthur, Duluth and Western Railway, in which are situated the mines, that with the exception of Silver Islet were the most important producers. There were the Beaver in O'Connor, Silver Mt. in Lybster, Badger and Porcupine in Gillies, and Rabbit Mt. in Scoble. The discovery of the Rabbit Mt. vein in 1882 led to the prospecting of this area. Mining was carried on systematically for about ten years.

Minerals of Port Arthur Veins

With the object of comparing the minerals of the Port Arthur silver mines with those of the Temiskaming veins, the following table has been prepared from the minerals mentioned by Ingall as occurring in the former:

I. Native elements:
Native silver, native bismuth, graphite.

II. Arsenides:
Niccolite, domeykite, macfarlanite (?), huntilite (?).

III. Arsenates:
Cobalt bloom, annabergite.

IV. Sulphides:
Argentite, zinc blende, galena, pyrite, marcasite, pyrrhotite, chalcopyrite, copper glance.

Fig. 102.—Silver Islet, Main Shaft and office.

V. Sulph-arsenide:
Mispickel.

VI. Antimonide:
Animikite.

VII. Sulph-antimonide:
Tetrahedrite.

VIII. Chloride:
Cerargyrite.

IX. Carbonates:
Malachite, azurite, witherite.

The vein filling materials are quartz, barite, calcite, dolomite, rhodochrosite and fluorite. Chlorite, saponite, inflammable gas and mineral water were also found. Mercury was found in the Silver Islet ore.*

*T. Macfarlane, "Am. Inst. M. E.", Vol. VIII, 1879-80, page 238.

Many writers appear to have held that the trap or diabase and gabbro which overlies the Animikie rocks in this region represented a vast surface flow. In a paper published some years ago Dr. A. C. Lawson showed, however, that this trap, together with the layers of the same material which lie at a greater depth in the Animikie, is intrusive in character (Fig. 96). His work proved that these traps are of the nature of intrusive sheets or sills, that they are not only younger in age than the Animikie, but that they belong to post-Keweenawan times.*

Of the diabase sills, Mr. N. L. Bowen says:† "The sills range in thickness from a few feet to five or six hundred feet. The evidence for their laccolithic nature is scanty because of the removal of overlying sediments, but in a few places small patches are left in such an attitude as to indicate an arching of the strata. An example is shown on a hilside on R. 40, Scoble.

"The diabase is a fine-grained, dark rock, composed of labradorite and augite in ophitic structure, with some biotite, apatite, iron ores, and generally a little quartz. In one specimen from a small sill, quartz was absent and considerable olivine present. A few feet from an upper or lower contact the diabase commonly becomes porphyritic,

Fig. 103.—Table hill, illustrating structure.

showing phenocrysts of feldspar. The phenocrysts have in many cases collected into bubble-like masses, 2 to 10 feet in diameter, anorthosites in composition, but lacking sufficient size to be considered geologic units. It is possible that by an extension of this process bodies of anorthosite might be produced."

Spar Island Vein

An interesting description of some of the veins and associated rocks is given in an older report, as follows:‡

"To the southwest of the mouth of the Kaministiquia several mining locations have been taken along the coast. The most interesting of these is that known as Prince's Mine, where there occurs a remarkable metalliferous vein, which is seen both on the mainland and on Spar Island opposite. On the south side of this island the vein has a breadth of fourteen and a half feet; and from its whiteness it contrasts strongly with the wall-rock, which is a dark-colored slate holding cone-in-cone. (Fig. 104.) Its course is about N. 32° W. The greater part of the vein is here occupied by a coarsely crystalline calc-spar; but near the middle are two bands, each of about twelve inches, the one composed of heavy-spar, and the other of quartz, mixed with calc-spar. Between these is a band of six inches of calc-spar, which is the only metalliferous part of the lode, and contains small quantities of yellow and variegated copper ores with native silver. Two

*"Bulletin No. 8, Geological Survey of Minnesota," 1893.
†"20th Report Ontario Bureau of Mines," 1911, page 127.
‡"Geology of Canada, 1863, pages 707 and 708.

shafts, one of twenty-four and the other of forty-seven feet, were sunk here. On the mainland, about two miles distant, and a little way back from the shore, the vein re-appears, somewhat split up; but a few rods farther to the northwest the parts reunite, and the vein is wider than on the island, and more quartzose, affording fine specimens of amethyst. It here contains small quantities of variegated and vitreous sulphurets of copper, with blende, and some native silver. A level was driven 165 feet in this vein, and at one place, in sinking a shaft of ninety feet, a bunch of several hundred pounds of ore was met with, which contained native silver disseminated in thin laminæ through

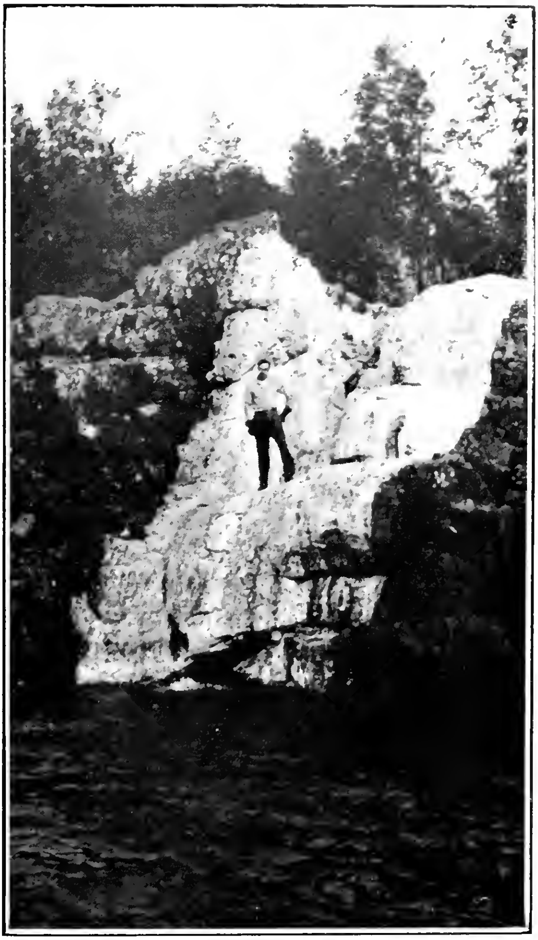


Fig. 104.—Spar Island Vein.

the calcareous spar and blende. This mass of rich ore was soon exhausted. Crystallized sulphuret of silver was also found in this vein; and the calcareous spar was stained with blue and green carbonates of copper, and with red arseniate of cobalt. Some further explorations were attempted after the discovery of this silver, but without success; and the mine has since been abandoned, although the characters of the lode are certainly such as should encourage further working for silver, if not as a copper mine. Adjoining this location to the westward is another in which the slates are intersected by large veins of calc-spar, sometimes associated with quartz, fluor-spar, and sulphate of barytes, and holding yellow and vitreous copper ores. At the mouth of the Pigeon river is

another location where numerous veins holding yellow and vitreous copper ores are met with, sometimes associated with blende."

Production of Port Arthur Area

Year.	Value.
Prior to 1887	$3,349,338 00
1887	190,495 00
1888	208,064 00
1889	162,309 00
1890	166,652 00
1891	221,120 00
1892	36,072 00
1898	51,960 00
1899	65,575 00
1900	96,367 00
1901	84,830 00
1902	58,000 00
1903	8,949 00
Total	$4,699,731 00

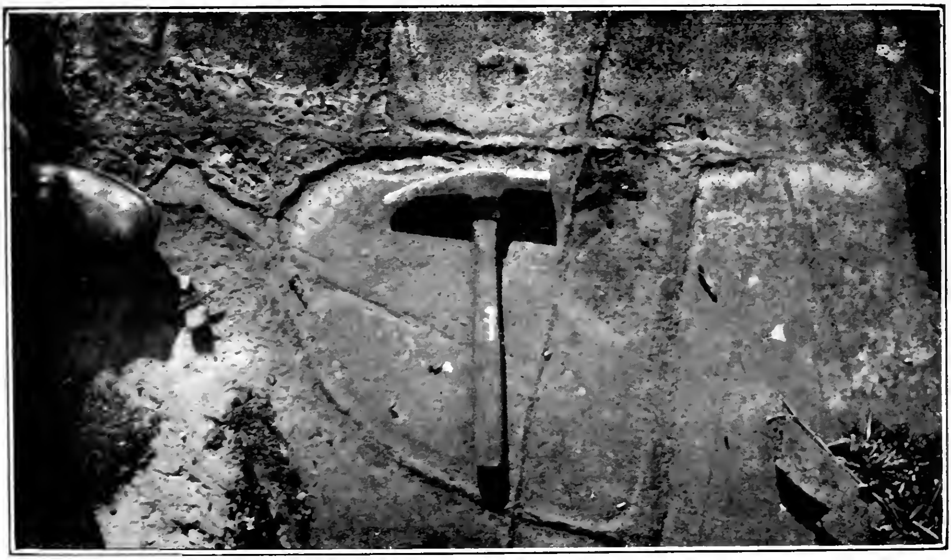


Fig. 105.—Top of diabase sill, showing contraction dikelets, lot 10, con. 1, township of Gillies.

Mr. W. A. Preston, M.P.P., has estimated the production of the individual mines as follows:

Silver Islet	$3,250,000 00
Silver Mountain, East and West	500,000 00
Beaver	550,000 00
Badger and Porcupine	300,000 00
Rabbit Mountain	50,000 00
Thunder Bay	20,000 00
Shuniah	50,000 00
3A. and Beck	10,000 00
Jarvis Mining Co.	40,000 00
Total	$4,770,000 00

It is thus seen that compared with Cobalt the production of the Port Arthur area was small.

Michipicoten Island*

The following notes on the occurrence of native silver and arsenical ores on Michipicoten island, lake Superior, are of interest. The occurrence resembles some of those in the copper mines of Michigan.

"The island of Michipicoten may next be noticed. On the north side of this island there is a considerable mass of greenstone and amygdaloid interstratified with sandstones, the whole dipping eastwardly. Towards the west end of the island, the rocks present a low surface for a breadth of four or five hundred feet, and then rise into a cliff two or three hundred feet in height, in which the greenstone is marked by druses containing analcime and quartz. A soft amygdaloidal bed holding native copper, is traceable for some miles along the shore, sometimes beneath the surface of the water in the bays, and again running a little distance inland. In this bed in the North Bay, an attempt was made, a few years since, to work a remarkable deposit of native copper and silver, which were found disseminated in grains through a green hydrous silicate of nickel. The ore being stamped, the nickel, whose value was not suspected, was washed away from the residue of native metals, which gave, in one trial, twelve parts of silver and eighty-eight of copper. A shaft was sunk here to a depth of seventy feet; but after a considerable outlay, the working was abandoned. Nothing very definite is known as to the mode of occurrence of this curious metallic deposit, which is stated, however, to have been associated with calc-spar. From the same mine were said to be obtained the specimens of mingled arseniurets of nickel and copper, which, with the preceding nickeliferous ore, are noticed on page 506, and again on page 737. At a point near the west end of the island, and about seven miles from the working just mentioned, the cupriferous stratum again appears, and fragments of the native metal are scattered along the shore. Mining operations on a small scale were undertaken here ten years since by the Quebec Mining Company, and a shaft was sunk at a little distance from the shore, in which the copper-bearing beds were reached at a depth of fifty-five feet. The mine is now leased to Mr. Hugh R. Fletcher, who is engaged in working it, and has kindly furnished the following particulars. Beneath the principal copper-bearing bed is a soft argillaceous rock known as an ash-bed, which is six feet, and perhaps much more, in thickness, and is underlaid by a massive greenstone. The ash-bed itself contains from one half to one per cent. of disseminated metallic copper, which it is supposed can be economically extracted by crushing and washing the soft rock. Upon this reposes the principal copper deposit. The metal is found in a bed of greyish amygdaloid of from eight to eighteen inches in thickness, and an overlying bed of sandstone of from twelve to twenty-four inches; the united thickness of the two being on an average about three feet. The proportion of copper is the same in the two rocks, and averages two and a half per cent. The copper is in larger grains in the amygdaloid, and is sometimes surrounded by calc-spar; while in the quartzose sandstone it is in fine particles, or in filaments. Small specimens of the sandstone are occasionally found containing ten or fifteen per cent. of copper. This bed is overlaid by a massive compact greenstone, to which succeed amygdaloid and conglomerate. The dip of the copper-bearing stratum is about three feet in a fathom. Three shafts have been sunk upon it, one to sixteen fathoms, one to twelve and a half, and a third to eight and a half fathoms. From 300 to 400 tons of two and a half per cent. ore have been raised; and in the spring of 1863 it is proposed to commence operations on a larger scale, with proper machinery. Small portions of native silver and of vitreous copper ore have been found in this vicinity; and according to Mr. Willson native copper occurs in a second band of amygdaloid about a mile and a half south of Mr. Fletcher's mine, and 200 feet above the surface of the lake. Vitreous copper ore is also found with calc-spar and sulphate of barytes on the eastern extremity of the island, in a reddish porphyritic rock, over which occurs a pitchstone porphyry and pitchstone with veins of agate.

"The arsenical ore already described as occurring on Michipicoten island has been shown to be an intimate mixture of the arseniurets of copper and nickel; different por-

*"Geology of Canada," 1863, pages 703 and 704.

tions of the same mass containing from seventeen to thirty-six per cent. of nickel. These results have been confirmed by Prof. Whitney, who, on visiting this locality, found this ore in the form of nodules, having a concentric structure, and imbedded in coarsely crystalline calc-spar. These, according to him, were irregularly distributed in the trappean rock, and did not form a regular vein. He found in two specimens, respectively thirty-one and thirty-three per cent. of nickel. Of the second nickel ore from the same locality, already described as a greenish earthy silicate of nickel, and yielding about twenty-four per cent. of nickel, little is known, except that the specimens brought from the mine were filled with small grains of native copper and native silver; and that large quantities of the green earthy material were said to have been crushed and washed to obtain these metals, the valuable ore of nickel being lost in the process. The analysis of a specimen, from which the native metals had not been separated, gave for one hundred parts: silver 2.35, copper 18.51, and oxyd of nickel 20.85. At the present price of the latter metal it would be worth nearly as much as the accompanying silver."*

* "Geology of Canada," 1863, page 737.

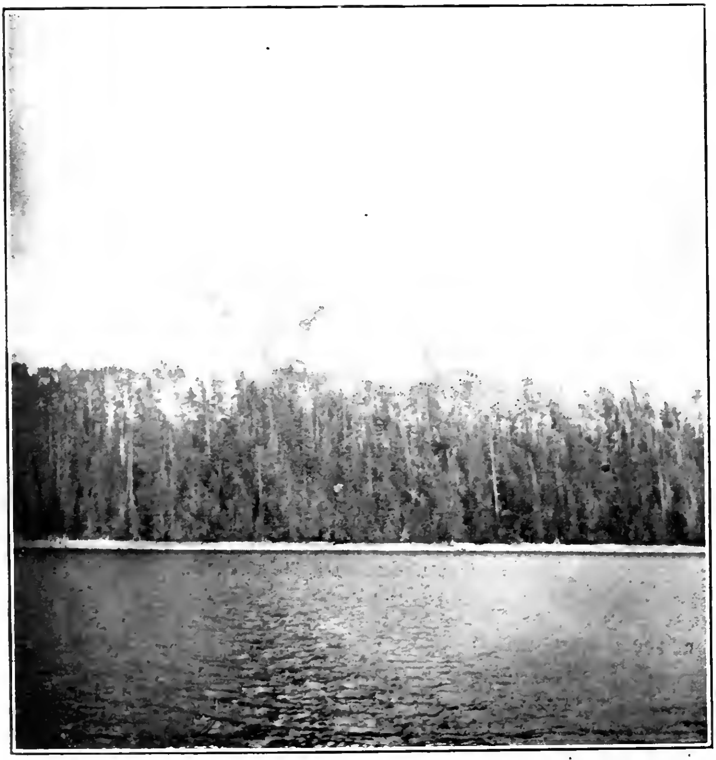


Fig. 105a.—Forest fire on the east side of Cobalt lake, opposite the railway station, June, 1905.

2. OTHER CANADIAN NICKEL-COBALT ORES

The following extract from the Report of the Geological Survey of Canada for 1890-91 summarizes the descriptions of a number of the occurrences of nickel and cobalt known in Canada at that time.

"It may not be amiss to draw attention here to certain other nickel and cobalt ores, or minerals containing a noteworthy amount of one or the other of these metals, which have from time to time been met with in Canada in the course of this Survey's work.†

"One of these, described as a steel-gray pyritous ore, from the Wallace mine on lake Huron, was found by Dr. T. S. Hunt to contain 13.93 per cent. of nickel. Of two others found on Michipicoten island, lake Superior, the one was shown by Dr. Hunt to be an intimate mixture of the arseniurets of copper and nickel; different portions of the same mass affording him from 17.03 to 36.39 per cent. of nickel, whilst the other, also examined by Dr. Hunt, proved to be a hydrated silicate of nickel which, after drying at 100°C., was found by him to contain 30.40 per cent. oxide of nickel. (equivalent to 23.91 per cent. nickel). The arsenide of nickel, which for present purposes may be regarded as consisting of 44.1 of nickel and 55.9 of arsenic, has also been found at the 3A mine, on lot 3A of the township of McGregor, district of Thunder Bay, where it occurs in somewhat large nodular grains and nuggety bunches, together with native silver, of a similar form, freely disseminated through a gangue of calc-spar with some quartz. The foregoing are all rich ores of nickel, and should the deposits on further exploration be found to yield a sufficiency of the material these would, as available sources of this metal, prove of economic importance.

"Less important, by reason of their occurring only in limited quantity or as containing but a relatively small amount of nickel or cobalt, are the following:—Millerite or nickel sulphide, a rich and valuable ore of nickel, occurs in small grains and prismatic crystals disseminated through a mixture of chrome-garnet and calc-spar in a vein on the east side of Brompton lake, in the township of Orford, Province of Quebec. It is also reported to have been observed, in the form of prismatic crystals, disseminated through certain portions of the nickeliferous ore of the Copper Cliff mine, in the township of McKim, district of Nipissing, Ontario. Erythrite or hydrous cobalt arsenate, a valuable ore of cobalt when met with in quantity, is mentioned by Dr. Hunt as occurring in rose-red incrustations on calcareous spar at Prince's mine on lake Superior. Smaltite, a cobalt arsenide, was observed by Mr. E. B. Kenrick in the form of minute crystals in a sample of copper pyrites (brought to the Survey for examination) from the township of McKim, district of Nipissing, Ontario. A sample of iron-pyrites from the seigniory of Daillebout, Joliette county, Province of Quebec, was found by Dr. Hunt to contain 0.55 per cent. of oxide of nickel (equivalent to 0.43 nickel) mixed with cobalt, and a brilliant compact variety of iron-pyrites from Elizabethtown, Leeds county, Ontario, yielded him from 0.5 to 0.6 per cent. oxide of cobalt (equivalent to 0.39 to 0.47 cobalt), whilst a sample of iron pyrites from Londonderry, Nova Scotia, was found by me (Rep. Geol. Surv. Can., 1874-75, p. 316) to contain 0.81 per cent. of cobalt and 0.14 per cent. of nickel."

The mineral danaite was found some years ago in developing nickeliferous pyrrhotite on the north half of lot 6, concession 3, of the township of Graham. Specimens of the mineral were found to carry about 4 per cent. of cobalt.

Cobalt bloom has also been found on magnetite at the Dominion mine and at the Cross mine, lot 2, in the second concession, in the township of Madoc, Hastings county.

In the western part of the Province the mineral occurs in small quantity at the southeast corner of the Bay of Islands, Bad Vermilion lake.

In the Report of the Geological Survey for 1848-9, page 61, T. Sterry Hunt has this to say concerning the ore of the Wallace mine at the mouth of the White Fish river, a partial examination only having been made of it:

†A more recent and fuller descriptive summary of the occurrences of nickel and cobalt minerals in Canada is given in the "Annual Report of the Geological Survey of Canada" for 1901, Vol. XIV, Part H, pages 147 et seq.

"The specimen was a mixture of a steel-gray arseniuret, the species of which I have not yet determined, with white iron pyrites and probably some arsenical sulphuret of iron."

The percentage of cobalt in this ore was slight, only a fraction of one per cent., while the nickel ran about eight per cent. He further says:

"The Wallace mine is the second place in which cobalt has been detected in Canada. I have already noticed it in the form of an arseniate of cobalt, forming reddish crusts upon calcareous spar, at Prince's location on lake Superior. In this locality it is associated with vitreous copper, green and blue malachite and native silver, while other parts of the same vein yield native silver, vitreous silver, blende and copper pyrites; in this connection it may be mentioned that a mass of silver ore selected by myself from some hundreds of pounds, as an average sample, gave on assay 3.6014 per cent. of silver, equal to 72 lbs. to the ton of ore. A portion of the silver extracted by a furnace assay from this ore was found on examination to contain a small portion of gold amounting to about one part in 7,000 of silver."

Speaking at this early date Hunt made the remark which, after a lapse of a lifetime, reads like a prophecy: "The detection of a small portion of cobalt in association with these metals upon the shore of lake Huron should lead us to look for deposits of this rare and valuable material."

Fig. 105b.—Cobbing and sacking ore at the La Rose mine, November, 1904.

3. FOREIGN COBALT DEPOSITS

GERMANY AND AUSTRIA

Known deposits of cobalt-silver ore in other countries which resemble, most closely, those in the vicinity of Cobalt station, are found in Germany and Austria. The two areas in these countries, to which special reference may be made, are those at Joachimsthal and Annaberg. Mining was begun in the former at the end of the fifteenth or in the early part of the sixteenth century. The deposits of the latter, it is said, were discovered in 1492, a year which possesses special interest for inhabitants of this continent, for then Christopher Columbus first sighted its shores.

The ores of those two regions are similar to those of Ontario, and include compounds of cobalt, nickel, bismuth and silver, with the ore of uranium, which has not been found in the Ontario deposits. With these are silver ores of various kinds. The rocks belong to the older systems, but are different in composition from those of Cobalt.

An outline of the history of the cobalt industry at Schneeberg, another German area which contains ores similar to those of Cobalt, Ontario, is given in an appendix to this Report.

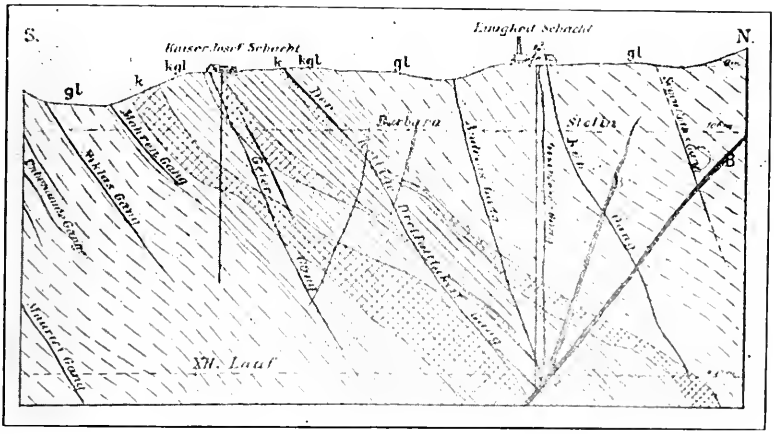


Fig. 106.—Vertical section through the Kaiser Josef and Einigkeit shafts at Joachimsthal showing several narrow veins (gang), and dikes of diabase (B). The veins in mineral contents, size and distribution resemble those of Cobalt, Ont. (After Babanek-Beck.)

At Joachimsthal, in Bohemia, there is a series of mica schist, calc schist and limestone which is cut through by dikes of basalt. The veins are said to be older in age than the basalt and cut all of the other rocks mentioned. The veins are narrow and contain quartz, hornstone, calcite and dolomite as gangue material, and they often show a brecciated structure.* The minerals in these veins are embraced in the following list:

(1) Silver ores (native silver, argentite, polybasite, stephanite, tetrahedrite, proustite, pyrargyrite, sternbergite, argentopyrite, besides rittingerite, acanthite and cerargyrite).

(2) Nickel ores (niccolite, chloanthite, millerite).

(3) Cobalt ores (smaltite as well as bismuth-bearing linnæite and asbolite).

(4) Bismuth ores (native bismuth together with bismuthinite and bismuth ochre).

(5) Arsenic ores (native arsenic, arsenical pyrites).

(6) Uranium ore (uraninite or pitchblende).

With these are galena, zincblende, pyrite, marcasite, copper pyrites and others.

Among these ores those of cobalt and nickel are generally the older; those of silver the younger. The veins cut through dikes of quartz-porphyry, and are in turn cut across by basalt and later dikes.

* Beck: "The Nature of Ore Deposits." Beyschlag, Krusch and Vogt: "Die Lagerstätten der Nutzbaren Mineralieu und Gesteine." Stelzner-Bergeat: "Die Erzlagerstätten."

Of similar composition to those of Joachimsthal are the veins of Annaberg in Saxony. In this neighborhood the rock is gray gneiss. There are two groups of veins in the district, the younger carrying the silver-cobalt ores. These are the most important of the ore bodies. The gangue material is chiefly heavy-spar, fluor-spar, quartz and brown-spar with various cobalt, nickel and bismuth ores, namely: chloanthite, smaltite, red and white nickel pyrites, annabergite, native bismuth, rarely bismuthinite. Of the silver ores there are pyrargyrite, proustite, argentite, native silver, silver chloride, and finally iron pyrites. The subordinate minerals are the gangue materials, hornstone, chalcedony, amethyst, calcite, aragonite, kaolin, gypsum; among ores are copper pyrites, galena, zincblende, marcasite, tetrahedrite, siderite, uraninite, uranochalcite, uranochre, gummite, native arsenic.

The great amount of chloride of silver, which was mined on a large scale at one time, is interesting. The structure of the veins is irregular.

From more than 200 observations which have been made the following is given as the relative ages of the various minerals of the Annaberg veins:

V. Decomposition products, for example, annabergite and cobalt bloom.
IV. Silver ores and native arsenic.
III. Calcite and uraninite.
II. Brown-spar and cobalt-nickel-bismuth ores.
I. Heavy-spar, fluor-spar and quartz.

The silver-cobalt veins cut across the older tin and lead veins of the district as well as the dikes of microgranite and lamprophyre. The latter, especially, is often cut by the silver-cobalt veins. These are cut by basalt, which occurs not only in true dikes, but also in boss-like forms.

Somewhat similar silver-cobalt ores are found in certain veins at Schneeberg, but they are not so strikingly like those of Temiskaming, in mineral composition, as are those of Joachimsthal and Annaberg.

A like association of ores is found at Wittichen, where the veins occur in granite.

In 1904 only one cobalt-silver mine in Germany had a production worth consideration. This is in the Schneeberg field. Its output was valued at about $132,147. The values were in silver, cobalt, nickel, bismuth, arsenic, uranium, samples, etc. The works in which these ores are treated in Germany are at Schneeberg and are known as the "blue color works." Both the government and private companies are interested in the industry. (See appendix III.)

According to Von Cotta, the Joachimsthal district consists of mica schist, together with more or less hornblende schist and crystalline limestone, the whole being cut by numerous dikes of quartz-porphyry and basalt. There are also two large granite masses which rise out of the mica schist. There are lodes of tin, silver and iron. Tin lodes are found only in the granite region. Silver lodes are divided into four groups tolerably distinct from one another. One set, which has a strike in a certain direction, contains about 17; another set has 21 lodes. There are also lodes which do not come to the surface. Both classes of lodes are said by Von Cotta to intersect the mica schist, with all its subordinate strata, quartz-porphyry and often even the dikes of basalt and wacké. This author also says that there seem to be cases where dikes of the last have intersected lodes or have penetrated into their fissures, from which it may be deduced that the silver lodes were almost contemporaneous with the formation of the basalt in that their fissures in part follow the basalt dikes, in part are intersected by the basalt. At all events they stand in a certain genetic connection to the porphyry, which here is evidently of much greater age than the basalt. The subject is still somewhat obscure. The silver lodes have not yet been found in the granite. Other writers do not agree with Von Cotta, as they appear to claim that the basalt is younger than the veins.

The following notes are taken from Phillips' "Ore Deposits," p. 436. The mountains known as Erzgebirge lie on the boundary betwen Saxony and Bohemia. Joachimsthal lies on the Bohemian side, and is therefore an Austrian town, while Annaberg is in Saxony.

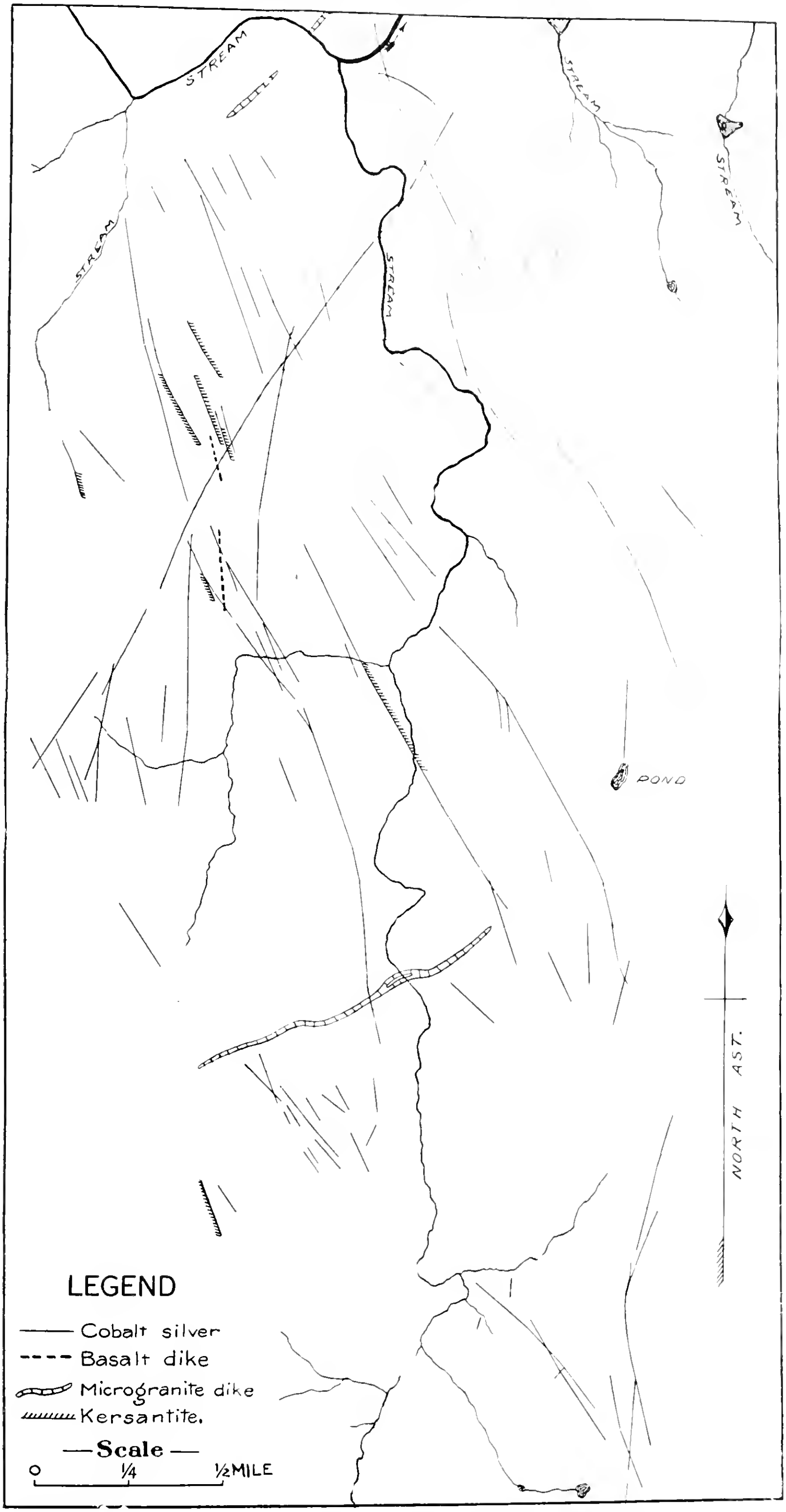


Fig. 107.—Map of part of the Annaberg area, Saxony. The thin lines represent the veins, the strike of which is more regular than of those at Cobalt.

The country rock in the neighbourhood of Joachimsthal is for the most part mica schist enclosed between masses of granite. In the eastern portions of the mine where there are some masses of included limestone, the lodes usually carry calcite as the predominating veinstone, but in the western part where the veins are not infrequently associated with dikes of porphyry, the gangue is almost entirely quartzose. There are seventeen veins striking north and south and seventen others of which the direction is east and west. It has been constantly observed that the former exhibit a tendency to become enriched where they pass through the porphyry or included limestone, while the latter set of veins are not similarly affected when they come in contact with these rocks. The ores raised contained values in silver, cobalt, nickel, bismuth and uranium.* In the eastern division of the mine there are two shafts situated about 260 fathoms apart, the Einigkeit's shaft and the Kaiser Joseph shaft (Fig. 106).

In 1864, when the former shaft had reached a depth of 280 fathoms, a heavy outburst of water, at a temperature of 25 C. and evolving sulphuretted hydrogen, took place and greatly interfered with undergound operations. It took two years before this water could be successfully tubbed off and mining proceeded with.

The character of the ore produced will be seen from the following statement made by Phillips:

During the period from 1877 to 1880 there were obtained 29⅓ tons of ore, containing 4,497 oz. of silver, 198 lbs. bismuth, 878 lbs. uranic oxide, 1½ tons arsenic and 314 lbs. of cobalt-nickel with a little lead, representing a total value of £1,687.

"About this time it became evident that the uranic oxide was the most valuable product of these mines, and workings were especially directed to develop the minerals yielding it. From 1881 to 1886 the average annual production was 38 tons of silver and uranium ores, worth about £6,520."

It is thus seen that these Joachimsthal veins, during late years at least, cannot be compared in richness with those of the Temiskaming district.

Cobalt, Annaberg and Schneeberg Compared

Number of Veins and Productiveness

The following interesting comparison of the veins at Cobalt with those of the old mining areas of Annaberg and Schneeberg is taken from a paper by Mr. George R. Mickle.†

" Let us compare the Cobalt district to the most productive silver districts in Europe, viz., Annaberg and Schneeberg, with regard to the number of veins. In order to do this intelligently, it will be necessary to understand the geological features, and also the industrial conditions under which the mining operations were carried on. Details of the mineralogical features of these European silver-cobalt veins are given in the report on the 'Cobalt-Nickel Arsenides and Silver' referred to before. The accompanying map of Annaberg is reproduced direct by a pantograph from the one attached to a monograph by Herman Müller (Die Erzgange des Annaberger Bergrevieres) and the information here is also taken mainly from the same source (Fig. 107).

" Briefly stated, the history of Annaberg was that after the first discovery in 1492 there was a rapid increase; in 1496 there were six mines paying dividends. The prosperous period lasted nearly fifty years, and the whole life of the district as a silver producer about one hundred years. It must be remembered, however, that no mechanical power was used and no powder in the mining operations, although it was long in use in warfare, and the rate of progress was probably only one-fifth, or even less, as rapid as it would be now. As a compensation wages were low, and the value of silver was very nearly three times as great as it is now, viz., $1.46 per ounce.

"A word as to the mode of operation will be in place. After a few successful ven-

* It is interesting to know that the uranium ores of Joachimsthal took on an additional value a few years ago, when it was found that uraninite was the chief commercial source of radium.

† "Journal of Canadian Mining Institute," 1910.

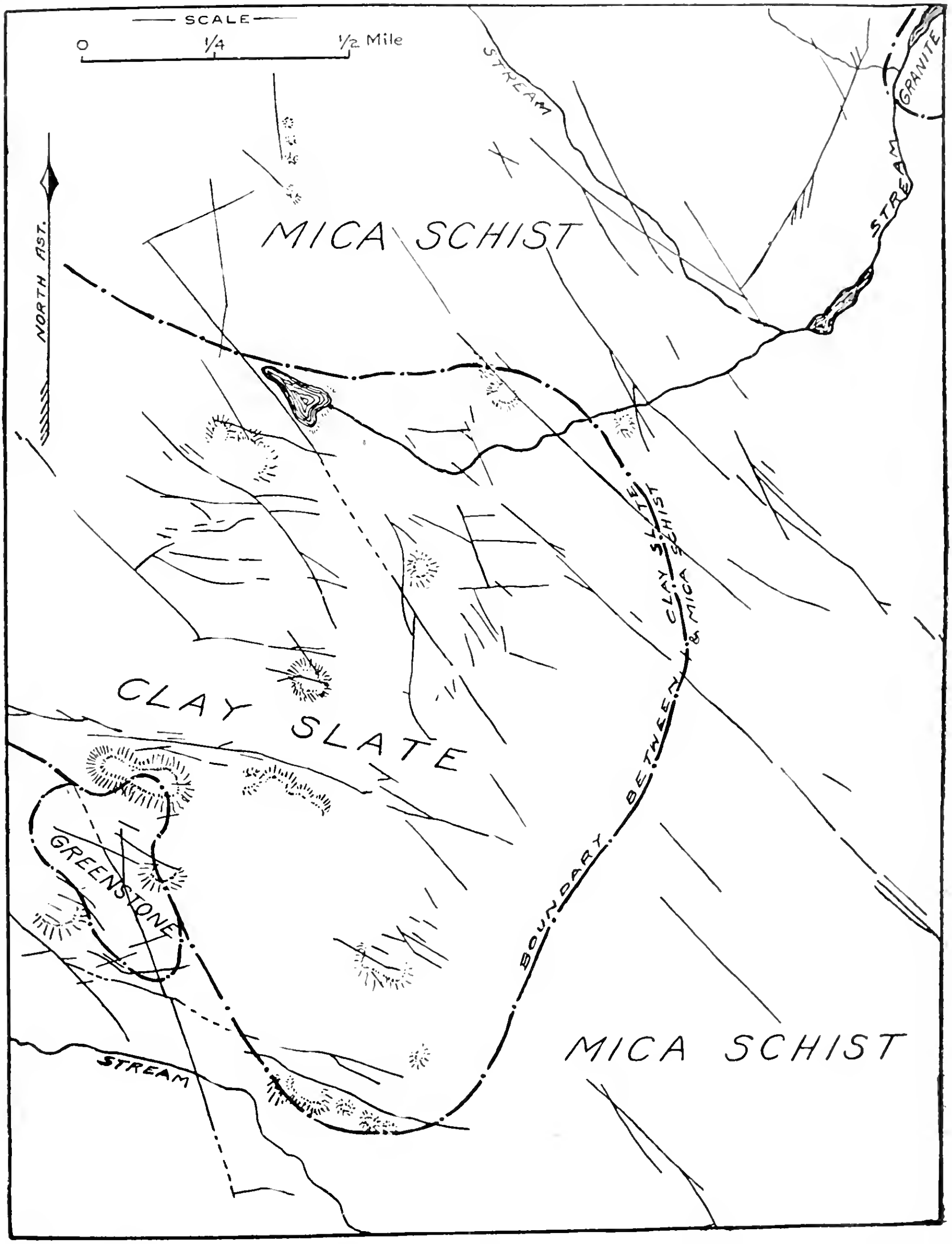


Fig. 108.—Map of part of Schneeberg area, Saxony. The thin lines represent the veins. Reproduced from map by H. Müller.

tures, a feverish mining speculation seized all classes of the community—town people and country people tried their luck. As soon as a vein was discovered, the exclusive right to work it could be obtained for a small fee from the mining office. It was the universal custom to divide the 'mine' into one hundred and twenty-five equal shares, to which were added four 'free' shares, one of which was given to the owner of the ground on which the discovery was made (that is all he ought to have), another each to the town, the hospital and the church. The silver produced from the rich ores was quickly converted into money at the mint, and the many fortunate enterprises attracted outside capitalists. The number of men employed as miners was about two thousand.

"The rock was soft, but very soon, as depth was attained, water began to give difficulty, and as there were no efficient pumps or means of ventilation, the work by shafts had to be abandoned. Fortunately, from the configuration of the ground long adits could be driven from the valleys to tap the veins. One system alone of these adits had a total length of sixteen miles. The maximum depth attained by any adit was about 700 feet.

"The term 'mine' was indefinite then as it is now, and as it will appear they were mostly small affairs; thus the records show that there were during the whole life of the district 635 mines that gave dividends; of these, however, over half, or 338, only lasted a year at most. The greatest number of profit-earning mines in any one year was 38, and the total number which produced silver was 969.

"The richest mine in the Annaberg district paid dividends in its best period at the rate of $220,000 per year. Sixteen of the leading mines are credited with a total dividend of about $1,850,000, and the whole sum paid in dividends amounted to $5,550,000, as far as recorded.

"From the information given the total silver production can only be very vaguely estimated. Cases are mentioned where dividends per ounce produced amounted to over one dollar, and about fifty cents per ounce profit is mentioned as the average of a number. It must be kept in mind also that it was the custom to divide whatever profit was made at once, so that, as soon as there was no profit, work had to be abandoned.

"Including good and bad, an average of twenty cents per ounce profit produced would give only about 28,000,000 ounces as the total production, and 50,000,000 would certainly be an extreme estimate.

"With regard to Schneeberg, which had a greater reputation, and was always spoken of as the greatest silver mining district in Germany, if there is any reliable information as to the production, the writer has not been able to find it. If we take it as 100,000,000, and it is more likely nearer 50,000,000, it would still be smaller than the probable total output of the Cobalt camp, which should not be less than 200,000,000 ounces. There is no doubt, therefore, that this greatly exceeds in actual amount of silver those older districts, although, of course, in value there may not be much difference.

"The Annaberg district proper embraced about twenty-one square miles. Generally taken with it were several outliers of small area. The total number of known veins was 215, and of these 152 were in the Annaberg area proper, but, as the records of more than 300 old mines were lost, it is certain that a number of veins are not included in the count. On the same ratio, as about 970 mines show 215 veins, 1,270 would show 290 veins, and of those about 200 would be in the Annaberg area proper of twenty-one square miles. This is equal to 336 claims of forty acres, or about .6 of a vein per claim. As we have seen, the Cobalt area of 2.90 square miles, or forty-six claims, has already disclosed sixty-six veins, or nearly 1.5 veins per forty acres, and has already far surpassed the Annaberg district in number of veins per unit of area.

"Looking at the map of the Annaberg district, an area of about eight square miles is shown with probably about 100 veins, this being the best part (only the cobalt-nickel silver veins are shown). It will be noticed that in many places the veins are grouped together. . . . A forty-acre claim could easily be placed on certain portions of the map to include five to ten veins, and also in many cases there would be blanks. Prac-

tically the whole area is taken up with one kind of rock—a biotite gneiss—the different dykes being so narrow that their area may be neglected. In a number of places kersantite dykes follow the veins. This can be seen at Cobalt, most easily at the large cobalt vein (No. 8) on R. L. 404, near Peterson lake.

"Coming to the Schneeberg district, according to Stelzner (Erzlagerstatten II, I. S. 738) 150 veins were found in an area of about ten square kilometres, or 3.8 square miles, or sixty-one claims of forty acres, or about 2.5 veins per claim. As on the Annaberg map, not all the veins are shown. About the centre the veins were massed very thickly. That is where the St. George mine was situated, which produced a larger nugget than any yet found in Cobalt. Notice the granite showing in the northeast corner. This was younger than the mica schist and clay slate in which the veins are found. A glance at the map shows that the slate and schist were equally favorable for finding veins.

"If the Cobalt area were equally productive in veins with the Schneeberg, then the number would be:—

$$\frac{2.9 \times 150}{3.8} = 114, \text{ approximately.}$$

"This is a difference of only about 14 per cent. in the number of veins in an equal area, considering the Huronian rock only. The estimate of the number in the Cobalt district cannot be expected to be closer than 10 to 20 per cent. of the actual truth. In the number of veins per unit of area, therefore, there is a striking resemblance between Schneeberg and Cobalt. It is not only in this respect that the similarity is seen; the way in which the veins occur in groups or clusters is also remarkable. Just as the values are concentrated in the veins in places, so the veins are concentrated in the country rock in certain spots, the degree to which this occurs being apparently about the same in the two districts. Thus about six productive veins on ten acres seem to be the maximum in both places; probably not over twelve or thirteen different veins fulfilling the conditions, as above mentioned, exist on any 40-acre claim. If the average number of veins for 40 acres is about three, and some have six or more, it follows that others must have none. How many there are of this kind at Schneeberg can be seen by subdividing the whole area into 40-acre claims. . . . This will give 63 claims, and of these eleven have no vein at all, and, therefore, were certainly worthless; and five more have such a short length of vein that they were probably worthless, or sixteen out of sixty-three, or say one in four, were valueless; three in four, therefore, were sure of success. It should be mentioned that about thirty of the veins are not shown on the plan of Schneeberg, this being a modern map produced from information gained in the period 1852 to 1893, when a determined effort was made to open up the mines at lower levels, in the hope that with modern appliances ore would be found which formerly could not be reached. This hope proved elusive; the old miners had taken out the best, and the results on the whole were disappointing. This plan shows everything projected on the plane of the lowest level. Veins not found on this level or which they did not try to find are missing therefore. If these thirty veins were distributed proportionately, it would reduce the number of the worthless claims by one-fifth, or make the chance of success about four in five. The length of the veins is, of course, a factor in this calculation, and it will be noticed that on the whole they are longer than in Cobalt, which would reduce the chance of success in the latter district somewhat.

"Up to the beginning of July, 1909, the number of productive veins appeared to have increased to eighty-four. It is difficult, however, to count within five or six of the correct number, as subsequent working proves sometimes that what appeared to be two separate veins is really one, and vice versa."

Chalanches, France

Somewhat similar silver, cobalt, and nickel ores occur in a network of narrow veins in crystalline schist at the Chalanches, in the Dauphiné, France. These deposits were discovered in 1767, and have had an interesting history. They were described some years ago by Mr. T. A. Rickard.*

The following extracts are from Mr. Rickard's interesting paper:

"In southeastern France, among the magnificent Alpine masses of the Dauphiné, there is a group of celebrated mines of silver, nickel and cobalt ores, the deposits of which present many features of interest. . . . .

"The discovery of these, as of many other notable mines, was accidental. In 1767, Marie Payen, a shepherdess (bergère) of Allemont, found an outcrop of silver ore, and brought away, in ignorant curiosity, a lump of heavy stone, which she handed to the village smith. When tested on his forge, the molten silver trickled from it. The shepherdess received 600 francs upon her wedding day as a reward for the discovery.

"The record of the Chalanches presents a story similar to that which is told of mines in more modern mining districts. The inaccessibility of the mines in winter, the richness of the ore, its great fusibility, and the consequent systematic robbery of the silver are local commonplaces. Circumstances all worked together to make the Chalanches mines the prey of the most barefaced plunder. With the aid of a common forge-fire, even without the intervention of a crucible, and with little knowledge or skill, lumps of silver could be produced from the very rich chlorides, ruby silver and black sulphides which constituted in the main the soft earthy ores or *terres* found in the crevices of the outcrop. Aged inhabitants still talk sportively of the theft like old smugglers and point out nooks in the woods, which the remaining ruins of the little furnaces dug out by the miners show to have been the scenes of former illicit silver-ore smelting. In these furnaces, no larger than an ordinary fire-place, dug in the earth and smeared with clay, with charcoal, or, failing that, clods of dung for fuel, and two or three little urchins to blow, like cherubs on the old maps, out trickled the white metal. Clergy and people joined cheerfully in these moonlighting operations without in any degree shocking local ethics. The priest at Allemont, who lately restored the parish church, says that the old church had a room adjoining the sacristy in which a former reverend father used to melt down silver-ore brought to him by the faithful. The slags were concealed in an excavation under the floor, where a large accumulation of them was found when the church was restored. . . . .

"During the earliest period of mining at the Chalanches, some bodies of extremely rich ore were found near the surface. It is said that two shots produced sufficient silver to pay for the two buildings known as the pavilions of Allemont, with their various ornamentations, including the *fleur-de-lis* which still adorn the roof. As 200 to 300 kilos. of silver would at that time be worth from $10,000 to $15,000, this statement does not seem incredible. . . . . . .

"It is not a little remarkable that although the silver is always associated in the lodes with rich nickel and cobalt ores, often with bunches of stibnite, and more rarely and erratically with gold, the government engineers took no notice of any metal other than silver. None of the valuable metals mentioned figure in the old accounts. The speiss containing nickel and cobalt was rejected with the slags, and went to fill the swamps and to form the road-beds, which, in later times, were furrowed and turned over to recover their valuable contents. . . . . .

"The possibility of utilizing three metals instead of one seems to have dawned upon the engineers quite as a discovery; and this fact stimulated the repeated spasmodic attempts to rehabilitate the old mine. The arsenides of nickel and cobalt were sold in England and Germany. More recently, a German chemist was employed at Allemont in an experiment to manufacture cobalt pigments for the arts. He was not successful, and the attempt was abandoned.

*"Transactions of American Institute M. E.", Vol. XXIV.

"In 1891 the gold value was first recognized. Its importance proved greater from a scientific than from a commercial point of view. The old mine-workings, aggregating 20 kilometres in length, showed that a great deal of unsuccessful exploration had been carried out. Search among the galleries, particularly near the surface, resulted in the finding of certain rich bunches of ore, which were soon exhausted. An attempt to introduce the tribute or lease system was made, with partial success. . . . . .

The Ore Deposits

"The geological formation is simple. A network of veins traverses crystalline schists of very variable character. The country forms a part of the great crystalline formation usually referred to as the Archaic schists of the Alps, though in point of fact they probably include rocks from the granite up to the Carboniferous. Lithologically, certain sections suggest the Huronian and Laurentian. These schists lie immediately upon the granite; they are extremely variable in character, so that at different places they can be described as gneissoid, granitoid, talcose, micaceous, graphitic, or amphibolic. At the base of the slope leading to the mines there are superb blocks of rock containing crystalline epidote. . . . .

"The maps of the mine exhibit a wonderful network of galleries, spreading like a cobweb over an area of about 600 by 300 metres.

"It is computed that the workings aggregate in length not less than twelve miles, an extent in remarkable contrast to the relatively small quantity of ore produced. . .

"It has been thought by several observers that the lodes were more numerous near the surface than in the interior of the mine. This is due to the fact that any single fissure, in approaching the surface, spreads itself out into a number of subordinate fractures. It has also appeared that the lodes gained in regularity as they penetrated the mountain. Caillaux, therefore, adds that this fact seems to indicate the probable occurrence in depth of only a small number of lodes, but that those surviving will have a regularity greater than those which have been hitherto exploited. Regularity of structure would be a poor compensation to the miner for the fact that the enclosing rock is much harder, and the thickness of ore smaller, than in the ground nearer the daylight.

"The veins vary in width from a knife-blade to 80 centimetres (31.5 inches); their usual thickness lies between 3 and 30 centimetres (0.1 to 1 foot). . . . . .

"Examination of the old workings proves clearly that with increasing distance from the surface the country gets harder, the veinstuff loses its soft character, the veins become fewer in number, more regular, less wide and less ore-bearing. Approaching the surface, on the contrary, the schists are fractured in a multiplicity of directions, the veins become larger, their filling is generally earthy and they throw off branches, at the intersections of which ore bodies are found. In general, mineralization becomes more pronounced with approach to daylight; this being due, not merely to the oxidation of the sulphides but to an actual relative increase of 'orey' matter. . . . .

"The observations made from day to day led me to conclude that the richest part of the mine was that which was within the influence of oxidation, and that both chemical agencies and structural conditions favored an enrichment of ore near the surface. This statement is particularly applicable to the silver contents. It also holds true of the gold, but it is less accurate with respect to the nickel and cobalt. The richness in silver of the oxidized ores suggests secondary precipitation. This is confirmed by the fact that the silver appears to be thrown down upon the nickel and cobalt arsenides, and often envelops them in such a way as to impart to them the rudiments of a nodular structure. The hard, undecomposed arsenides contain only small amounts of silver. The gold, only occasionally present, is associated invariably with soft, maroon-colored, earthy, iron-bearing vein stuff. The nickel and cobalt minerals appear to be primary ones, and are more persistent than those of silver and gold. . . . . .

"If we accept the current theory that the nickel and cobalt came from the leaching of magnesian silicates (and facts are numerous pointing that way), then, we must con-

clude that the origin of the nickel and cobalt of the Chalanches was not the immediately enclosing country, but rocks similar to it, which underlie it at a greater depth. The silver and gold, it may be suggested, were precipitated from other solutions, and at a period other than that which saw the deposition of the nickel and cobalt. The precious metals were probably derived from a deeper-seated source; and may have been leached from the granite which underlies the schists and is penetrated by the basic eruptives. In both cases the various metals must have come from a depth where leaching action was powerful, and from which ascending currents brought the metallic constituents, the subsequent precipitation of which produced valuable ore-deposits."

Norway

"The cobaltiferous fahlbands of the districts lying around Skutterud and Snarum occur in crystalline rocks varying in character between gneiss and mica schist, but from the presence of hornblende they sometimes pass into hornblende schists. These schists of which the strike is north and south and which have an almost perpendicular dip, contain fahlbands very similar in character to those of Kongsberg. They differ from those of that locality, however, inasmuch as while here the fahlbands are often sufficiently impregnated with ore to pay for working, those of Kongsberg, although to some extent containing disseminated sulphides, are only of importance as zones of enrichment for ores occurring in veins. The ore zones usually follow the strike and dip of the surrounding rocks and vary in breadth from 2½ to 6 fathoms. The distribution of the ores is by no means equal, since richer and poorer layers have received special names and are easily recognized. The predominant rock of the fahlbands is a quartzose granular mica-schist or gneiss. The ores worked are cobalt-glance, arsenical and ordinary pyrites containing cobalt, skutterudite, magnetic iron pyrites, copper pyrites, molybdenite and galena. It is remarkable that in these mines nickel ores do not accompany the ores of cobalt in any appreciable quantity. The principal fahlband is known to extend for a distance of about six miles, and is bounded on the east by a mass of diorite which protrudes into the fahlband, while extending from the diorite are small dikes or branches traversing it in a zig-zag course. It is also intersected by dikes of coarse-grained granite which contain no ore, but which penetrate the diorite."*

These deposits, which at one time were among the world's chief producers of cobalt, are too low grade to be now worked at a profit.

At Kongsberg are famous silver veins, discovered in 1623. In width, in the character of the gangue, which is essentially calcite, and in the fact that numerous veins or stringers occur in small areas, the veins resemble those of Cobalt. Nickel and cobalt minerals are, however, not characteristic of these Norwegian deposits.

New Caledonia

As the table given below shows, there have been during late years about half a dozen countries supplying the world with cobalt. The output of New Caledonia, at the time Cobalt was discovered was much larger than that of any other country. It produced probably 85 or 90 per cent. of the world's supply.

When the ore from Ontario was put on the market, the prices fell materially in New Caledonia, and cobalt mining has now practically ceased in that country. It seems strange that Ontario should be the only serious competitor which this French penal colony, in the southern Pacific, has in both nickel and cobalt. The rivalry between the two countries in the production of the former metal has attracted attention for a number of years. It is now the more surprising that this Province has destroyed the cobalt industry of the island.

The cobalt deposits of New Caledonia occur under similar conditions to those of nickel and the two metals are frequently associated in economic quantities. The deposits of the two metals in Ontario, on the other hand, occur under conditions dif-

*Phillips: "Ore Deposits."

ferent from those of New Caledonia, and little connection has been proved between the cobalt deposits of Temiskaming and the Sudbury nickel ores ninety miles to the southwest. The Sudbury ore consists of pyrrhotite and copper pyrites. It is associated with basic igneous rocks, the deposits being supposed to be of igneous origin. The cobalt silver deposits, on the other hand, occur in distinct veins and are of aqueous origin.

It may be added, however, that the Cobalt and Sudbury areas appear to belong to the same "petrographical province," the diabase and the cobalt of the former area seem to have been derived from the same magma. This diabase is characterized by the presence of free silica, quartz, as is also the coarser grained igneous rock, norite, associated with the Sudbury nickel deposits. A comparison of the ore deposits of the two areas is given in Chapter I.

New Caledonia is a non-glaciated country. Over a considerable part of its surface the immediately underlying solid rock belongs to the basic igneous group known as peridotite. This rock, like other basic varieties, weathers readily, and over a large part of the surface of New Caledonia it is represented by its alteration product, serpentine. The surface of this serpentine is more or less broken down, forming comparatively loose or slightly coherent deposits. It is in association with these that the cobalt is found, its ore being what is known as asbolite, earthy cobalt or cobaltiferous wad. Asbolite is a mixture of oxides of cobalt, manganese and other metals. It can hardly be called a distinct mineral. It has been proved that the cobalt, nickel and other metals found in this decomposed rock were originally constituents of the peridotite.

The peridotites are believed by some writers to be post-Cretaceous in age, and are said to be in the form of a surface flow covering the uneven or eroded surface of the underlying Cretaceous strata.

They constitute the great serpentine formation of New Caledonia, and are high in magnesia and low in iron. They are more or less charged when fresh with crystals of pyroxene, uniquely ferro-magnesian, which lies between enstatite and bronzite. The unaltered rock belongs, therefore, in Rosenbusch's classification, to harzburgite. Dunite, which is composed of olivine with chrome iron ore and without pyroxene, is met with at times. These peridotites usually show traces of advanced alteration which results in the more or less complete transformation of olivene to serpentine, and in the development of talc from pyroxene. At times the alteration is complete enough to produce perfect serpentines, uniquely constituted of an aggregate of crystals of antigorite with some films of talc.

Since these rocks always contain a little manganese, nickel and cobalt, it would appear that these metals are integral of the olivene as well as of the enstatite. Grains of chrome ore are abundant in all samples.

The rocks are often traversed by dikes, less basic, of the character of gabbro, that is to say, rocks which contain feldspar and pyroxene. Diorites fine in grain or at times holding large crystals of hornblende sometimes outcrop in the middle of serpentine exposures.

Much of the mineral mined appears to contain only two or three per cent. of oxide of cobalt. After washing, it averages probably 4½ per cent. In one deposit described by Glasser, it is said that the decomposed material occupies a profound depression in the serpentine. This basin is filled by a red, clay-like deposit which has a depth of about 52 metres in the centre and 10 or 12 metres around the border. The richest ores appear to occur near the centre of the basin and near the contact of the serpentine.

It will be seen that all the cobalt deposits are irregular in form, and hence it is difficult to estimate their value.

The cobalt ore was all exported in the unrefined state.

The metal came on the market in the form of oxide, CoO, which finds use in small quantities in several industries, the principal being that of pottery, where the blue coloration which it tends to give to the ware is employed to counteract the reddish tinge that traces of iron so often produce. It is also used to color porcelain, enamels and

glass. The properties of metallic cobalt are remarkable. It would be used in alloys and for purposes to which nickel is put if it were as low in price as the latter metal. The different uses of cobalt, which absorb annually about 200 to 250 tons of oxide, guarantee a regular demand for the ore.*

Mr. A. Glasser, from whose "Report in 1904 to the Minister of the Colonies on the Mineral Wealth of New Caledonia" the foregoing is taken, states that New Caledonia has practically a monopoly of the production of cobalt in the whole world. He further says that while the deposits of the mineral are capricious they are at the same time numerous and extended.

This monopoly has now been broken by the discovery of the Ontario deposits.

At the time of Mr. Glasser's visit to the colony, the prices paid for cobalt ore were about as follows:—

Mineral with 4 per cent. CoO .... 330 Fr. a ton ($66).
Mineral wih 3 to $3\frac{1}{2}$ per cent. paid on the same basis, 145 fr. and with an increase of .60 fr. for each 1-10 of 1 per cent., above .... 195 Fr. a ton.
From 4 to 5 per cent., for each 1-10 of 1 per cent. above 4 per cent., there was paid .... .80 Fr.
From 5 to 6 per cent., for each 1-10 of 1 per cent. in excess of 5, was paid .... .90 Fr.
From 6 to 7 per cent. for each 1-10 of 1 per cent. above 6, was paid .... 1. Fr.
Above 7 per cent., for each 1-10 of 1 per cent., was paid... 1.50 Fr.
On this basis mineral carrying 8 per cent. brings 750 Fr. ($150) a ton.

In 1905, New Caledonia shipped the following number of tons of cobalt ore to the countries named, viz.: England 3,352, France 2,238, Australia 1,792, Germany 537, or a total of 7,919 tons, which is over 1,000 tons less than the shipments of 1904.

The following are the shipments of cobalt and nickel ores for the last three years:

	1905.	1906.	1907.
Cobalt	7,910	2,487	3,942
Nickel	125,289	130,688	101,707

The prices paid for cobalt ore in New Caledonia during the first quarter of 1908 were about as follows:—For $4\frac{1}{2}$ per cent. $23 (115 fr.) a ton; for 5 per cent. ore $27 to $28 (135 to 140 fr.), and 90 cts. (4.50 fr.) for each one-tenth of one per cent. above. At these prices, it is said, only the richest, well situated and developed mines can be worked. Many of the smaller mines have been obliged to close. An 8 per cent. New Caledonia ore at the price quoted would bring $36 a metric ton.

The Anglo-French Nickel Company of Swansea, Wales, who have been buying ore at Cobalt for the cobalt contents alone, pay 30 cents a pound for the metallic cobalt in an 8 per cent. ore. This is about $53 per ton for such ore. It is to be concluded, therefore, that the Canadian ores are preferred to those of New Caledonia by the refiners.

*It may be added that the method of manufacturing blue cobalt glass has been known almost from pre-historic times, as the glass has been found in the graves of the ancient Egyptians and in the ruins of Troy.

Production of Cobalt 1896 to 1900

Country	1896		1897		1898		1899		1900	
	Tons	Value	Tons	Value	Nons	Value	Tons	Value	Tons	Value
		francs		francs		francs		francs		francs
New Caledonia..	4,823	482,300	4,757	475,700	2,373	237,300	3,294	336,000	2,438	275,500
New South Wales	.....	....	.....	....	119	14,000	193	22,975	145	39,750
Chili..........	.....	....	6	780	18	4,540	55	20,450	27	10,060
Spain..........	18	9,000	13	17,000	.....	....	.....	....	.....	....
Norway........	19	13,500	24	13,500	21	10,800	.....	....	.....	....
Prussia........	181	49,340	121	31,280	34	8,500	17	4,250	4	800
Total......	5,051	554,140	4,921	538,266	2,565	275,140	3,559	383,675	2,614	326,110

1 franc = 20 cents.

This total was augmented by some tons of complex mineral mined in different parts of Germany and Austria, from which a little cobalt was produced.

Taking the world's consumption of cobalt oxide, CoO, at 200 to 250 tons a year, as given above, the 2,614 tons of ore produced in 1900 would need to contain on the average over 8 per cent. of the oxide. The price of the ore averaged, as shown by the table, approximately 125 Fr. or $25 a ton. It may be added that cobalt oxide, CoO, contains 78.66 per cent. of cobalt and 21.34 per cent. of oxygen by weight. The Temiskaming ore is sold on the basis of metallic cobalt, not on that of the oxide as in New Caledonia. But nothing is paid for much of the cobalt in the silver ores sold at Cobalt.

New South Wales

The second largest producer of cobalt in the world, before the discovery of the Temiskaming deposits, was New South Wales. The deposits in this country are situated near Port Macquarie and are similar in character to those of New Caledonia.

In 1903 the quantity of cobalt ore exported from the deposits near Port Macquarie amounted to 153 tons, valued at £1,570.

South Australia

Cobalt ore, containing smaltite and other minerals, is found at Bimbowrie, near Olary, on the Broken Hill line, but little work has been done on the deposit.

South Africa

While silver has, as we have seen, been worked in association with cobalt, the latter metal has been very seldom found in association with gold in important quantities. Reference to only one such occurrence has been seen by the writer. This is in the Middleburg district in the northern Transvaal. Here in this non-glaciated district the gangue material, in the vein to which reference has been made, is kaolin, with which is mixed gold-bearing quartz. In the latter mineral are small nest-like aggregations of smaltite and copper ores, and at times molybdenite and the secondary minerals cobalt bloom, limonite and skoradite.

In a publication a few years ago, a brief account of one of the cobalt deposits is given in the following words:* "Cobalt, in the form of smaltite and erythrite, is found at Balmoral, and also just beyond the northern boundary of the map in the valley of the Kruis river. At Balmoral the cobalt is associated with felspar and actinolite, together with secondary quartz and calcite, in veins most probably of igneous origin, which traverse a series of highly altered sedimentary rocks of shaly character in the neighborhood of the junction of the Waterberg and Transvaal systems."

*"Geology of the Neighborhood of Middleburg," Transvaal Mines Dept., Pretoria, 1907.

It will be seen that these South African cobalt veins resemble those of the Montreal river area, Ontario, described on a preceding page, in that they contain felspar and appear to be of igneous origin.

United States

Up to the present time there has been more or less production of cobalt oxide in the United States. Some of this came from the cobalt associated with the nickel ores at Sudbury, Ontario. In the process of smelting, which is now used at Sudbury, the cobalt is slagged out of the matte. Hence none of this metal will be produced in the future from Sudbury matte in the United States. According to the "Mineral Industry," in 1902 there was no production of cobalt oxide from domestic ores in the United States. In 1901, 13,360 lbs. of cobalt were derived from slag produced in the smelting of the lead ores at Mine La Motte, Missouri. In 1903 cobalt and nickel are said to have been discovered near Marion, Kentucky, in association with the fluorspar in that region. In the same year the Mine La Motte Company undertook the construction of a smelter and refinery for treating the nickel and cobalt ores obtained in connection with lead mining. A refinery was afterwards operated at Fredericktown, Mo., but is now closed.

It is said that a few years ago one or two small trial shipments of cobalt ore from deposits in Grant county, Oregon, were made to France. The deposits in this county are described as occupying fissures in a dark-greenish, more or less altered diabase-porphyry. They have a general northeasterly and southwesterly strike, and dip southeast. The ore bodies appear to be more or less lenticular in shape and vary from a few inches to several feet in width. The principal minerals are chalcopyrite, smaltite, arsenopyrite, pyrite, pyrrhotite, malachite and bornite with a quartz and calcite gangue. The values are chiefly in gold, cobalt and copper. Smaltite from a sample of the ore carrying this mineral and chalcopyrite was found by Mr. Burrows to have the following composition (No. 1). This smaltite had a rather unusual appearance, resembling somewhat acicular or fine columnar stibnite. In composition it is close to that from Gunnison county, Colorado, an analysis of which is given by Dana (No. 2).

	No. 1.	No. 2.
Cobalt	14.88	11.59.
Nickel	1.12	trace.
Arsenic	64.06	63.82.
Sulphur	.57	1.55.
Iron	11.14	15.99.
Insoluble	2.22	etc.
Calcium carbonate	6.34	
Total	100.33	

Mexico

Cobalt-holding minerals have been found at several localities in Mexico. Little has, however, been published concerning these occurrences. Near the village of Pihuamo, state of Jalisco, cobalt minerals are found in veinlets cutting a large vein of magnetite associated with pyrite and pyrrhotite. The chief rock in the vicinity is described as andesite. It is said that some tons of ore have been mined which contained 8 or 9 per cent. of cobalt. The minerals are cobaltite together with small quantities of smaltite and cobalt bloom. The veinstones are calcite, slightly greenish, and a little barite. A little niccolite appears to be present.

The following Mexican localities are also said to contain cobalt minerals: Iturbide, in Chihuahua, Guanacevi in Duranago, Cosala in Linaloa, at the mine "Mirador"' in Jalisco. It is said that the zinc in smithsonite is partly replaced by cobalt in Baleo, Lower California.

Chili

From the table on a preceding page it will be seen that Chili has been a producer of cobalt. References to the occurrence of the metal in that country are few, and the writer is not able to say what the ores are. According to Dana smaltite occurs, but in small quantities, at the silver mines of Tres Puntas and elsewhere in Chili.

4. METALLURGY

The characteristics of the metal cobalt and its compounds are much like those of nickel and its compounds. The methods used for extracting one metal from its ores are similar to those used in the case of the other. Since these methods are complicated, an attempt will not be made to describe them. The reader, desirous of a knowledge of the methods, is referred to some standard work on metallurgy, such as that of Schnabel.

In former times cobalt glass, "blue color," was made directly from some of the purer ores carrying cobalt, nickel, silver and arsenic. Most of the arsenic was first roasted off, and to the residue were added the constituents of potash glass—powdered quartz and carbonate or other compound of potash. The roasted ore, with these constituents added, was then melted down, the cobalt uniting with the glass to form smalt and the nickel and silver settling to the bottom of the furnace. If a little arsenic was not left in the ore some of the nickel would also combine with the glass, thus injuring its color.

The blue glass, or smalt as it is called, was powdered and sieved, and was then ready for the market. An interesting account of this method of manufacturing smalt is given in Knapp's "Chemical Technology," first American edition, Vol. II, 1848.

Cobalt now comes on the market in the oxide form, CoO. There are seven or eight manufacturers of this oxide in Europe—three in England and two or three each in France and Germany. The producers in Ontario are the Coniagas Reduction Company at St. Catharines, the Deloro Mining and Reduction Company at Deloro, and one or two smaller plants. Little cobalt is used in the metallic form, owing to the fact that nickel serves practically the same purposes as metallic cobalt and is much lower in price. It is said that a little cobalt added to nickel in plating tends to produce a more silvery and less steel-like lustre. By far the largest consumers of cobalt are the potteries.

APPENDIX I.

THE PALEOZOIC ROCKS OF LAKE TEMISKAMING

The limestones with, in places, basal sandstone and conglomerate that are found on the shores and certain of the islands of the northern part of lake Temiskaming, are much younger than the cobalt-silver deposits, and thus are of little interest in this report.

The character of the limestones and the uses to which they are adapted are described briefly on a preceding page. The fact that one, at least, of the great faults of the region has dislocated the limestones has also been mentioned.

In his report on the "Geology and Natural Resources of the area included by the Nipissing and Temiskaming Map-Sheets," Dr. A. E. Barlow has given a good description of these Paleozoic rocks of lake Temiskaming.* Since this description will be of interest to students and others visiting the lake it is reprinted in following paragraphs.

SILURIAN

Clinton and Niagara.

"The rocks of this age exposed on the shores and islands of the northern portion of lake Temiskaming have been of exceptional interest to geologists ever since their discovery and description by Logan in 1845.† Geographically, this outlying patch is so widely separated from any locality where rocks of similar age are now known to exist, that it has been a question whether it is indicative of an area of marine submergence connected with that in which the fossiliferous strata of Hudson Bay were deposited, or whether it was in some way connected with the Niagara basin to the southwest. It has been previously asserted that these rocks belong rather to the great northern trough connected with Hudson Bay, of which they are probably an outlier, and the absence of all strata of Niagara age in the region bordering the lower Ottawa has served to strengthen this belief. Although in lithological character and colour the rocks of similar age exposed on Temiskaming exhibit a marked similarity to the Niagara exposed further to the north, the rich and varied fauna characteristic of this outlier presents no corresponding resemblance, but rather a close analogy with the Niagara formation of southwestern Ontario.

"It has been shown that a pronounced similarity exists both in lithological character and fossil remains between the Niagara of the Winnipeg basin and that exposed in the vicinity of the Churchill on Hudson Bay, although these areas are now widely separated, while both present organic forms that are entirely lacking in the Temiskaming outlier. These facts, therefore, seem to prove that the seas in which the Niagara sediments of the Winnipeg basin and of Hudson Bay were deposited were practically continuous, while both were separated from the Temiskaming basin and the region to the southwest. The strata forming the Temiskaming outlier occur in the form of a shallow synclinal trough, occupying somewhat more than the breadth of the lake, which is here about six miles, and extending from the northern end of Moose or Bryson island northwestward beyond the confines of the present map. On both sides of the lake the rocks incline towards the water at varying angles, depending on the character of the shore-line; although in general the dip does not exceed 10°, and angles of lesser amount are far more common. On Mann or Burnt island, as well as on the peninsula to the north, the limestones show a very gentle westerly inclination of between one and two degrees, while on Percy or Farr island, near the west shore, the rocks are very nearly, if not quite, horizontal. It is thus evident that any section made must of necessity be more or less ideal, and any thickness based on the observed angles of the dip is sure to be

* "Geological Survey of Canada," Vol. X, 1897, Part I. The colored geological map, scale 1 mile to 1 inch, that accompanies this volume, shows the localities mentioned in the text.

† "Report of Progress," Geol. Survey of Canada, 1845-46, pp. 69-70. "Geology of Canada" (1863), pp. 334-336.

misleading. The whole thickness exposed in any one section is somewhat less than 150 feet, and it seems certain that the total amount of the Niagara exposed on this lake cannot be greater than 300 feet, and may be considerably less. The occurrence of loose angular fragments and slabs of grayish dolomite, resembling that exposed in the vicinity of lake Huron and Nipissing and containing characteristic Trenton fossils, has been noticed.* These are distributed at several points on the shores of the lake and specimens were collected from the northeast shore of Chiefs' island. Although their source has not yet been ascertained, the angular character of the fragments and their abundance shows clearly that this cannot be far distant. The lake is here over 200 feet in depth, and it is just possible that below the Niagara limestone and concealed beneath the waters of the lake there exists an area of Cambro-Silurian rocks. This, however, can only be ascertained by boring, as no exposures of these rocks were encountered, although a diligent search was made with this object in view.

"The relatively smaller quantity of conglomerates and sandstones, characteristic shallow water deposits, and the rapid alteration from these coarser clastics to the fine-grained limestones indicative of deep water deposition, point to a rather sudden marine invasion; while the comparatively great volume of strata remaining shows a prolonged submergence. The fine-grained character of most of the limestones show that their deposition took place in a quiet arm or extension of the sea, not affected by the open ocean, while the abundance and character of the fossil remains are ample testimony of the genial character of its waters.

Wabis Bay

"As exposed on the west side of Wabis bay, in the northwest corner of the lake, the lower portion of this formation is composed of a loosely coherent sandstone or grit alternating with thinner beds of a fine conglomerate, with pebbles chiefly of Huronian quartzite, most of which have a thin coating of yellowish or brownish iron oxide, while the matrix consisting of similar material in a finer state of division, contains a slight admixture of calcareous matter. The actual contact between this and the underlying slate of the Huronian is not seen, although only a few yards intervene between the exposures of the two rocks. The existing relations can, however, be made out pretty clearly, for while the compact and rather massive slaty rock which here represents the Huronian occurs in exposures with more or less rounded or hummocky outlines, the arenaceous strata of the Niagara dip off or away from these hillocks at an angle of 5°.

Haileybury

"At Haileybury, on the western shore of the lake, close to the water's edge and cropping out from the shingle is a small exposure of light-yellow, fine-grained limestone, without visible fossil remains, dipping northeast 25°. The discovery of limestone with the general contour of the country in its vicinity, seems to suggest that a small patch of Niagara extends northerly along this shore towards Wabis bay, being perhaps three miles in length by about a quarter of a mile in breadth, underlying the clay which here effectually conceals any rocks which may be beneath.

Percy or Farr Island

"Farther south, on Percy island, which is only a few chains in length and is separated from the western mainland by a very shallow and narrow channel, the rock exposed is a light-yellowish limestone, presenting a very uneven or cavernous surface as a result of unequal weathering. The strata are nearly, if not quite, horizontal, and weather from yellow to brown or almost black, as a result of the iron present. Shells of various species of brachiopods are somewhat numerous.

"A number of the fossil remains collected have been determined by Dr. Ami as follows:—

*"Geology of Canada" (1863), p. 335.

Clathrodictyon fastiguatum, Nicholson.
Favosites Gothlandica, Lamarck.
Syringopora Verticillata, Goldfuss.
Crinoidal fragments.
Leptæna rhomboidalis, Wilckens.
Atrypa reticularis, Linæus.
Meristella, sp.
Anoplotheca hemispherica, Sowerby.
Pterinea, sp.

Also branches of obscure Monticuliporidæ.

"This fauna represents the Clinton or base of the Niagara or lower part of the Silurian.

Chiefs' Island

"The northern and western points of Chiefs' Island rise into comparatively high ridges of massive quartzose sandstone or quartzite-grit, which present the usual rounded and glaciated outlines. Sheltered in the bay intervening between these two points is a small patch of boulder conglomerate, composed of sub-angular masses derived from the underlying quartzite. These are imbedded in a calcareo-arenaceous matrix composed chiefly of pebbles and finer material, the whole representing evidently a boulder-strewn beach covered by later sediments of the Niagara formation. The surface of the quartzite on which this conglomerate rests presents the hummocky character so common in the case of the hard Archæan strata, the irregular cracks and depressions being filled by the conglomerate. Subsequent glaciation has removed much of the material, so that the exposure now presents a plane surface with a more or less net-like structure, the framework being represented by the finer arenaceous cement, while the meshes or interstices are occupied by truncated sections of quartzite boulders as well as of the rounded hillocks of the solid rock beneath. Some of the boulders present in this conglomerate were evidently large concretions, as they exhibit concentric structure and weather very rusty owing to the disintegration of the large proportion of iron present. The finer cementing material, while relatively much smaller in amount than the pebbles and boulders, is always of a greenish or yellowish colour, and frequently contains corals and orthoceratites. The action of the weather partially obliterated the glacial striæ on this finer matrix, but the sections of the quartzite boulders and hummocks exhibit these markings in great perfection.

"On the southwestern shore of Chiefs' island is another small patch of a finer grained conglomerate, the pebbles of quartzite being less numerous and of much smaller size, while the matrix contains much more calcareous matter. The rock dips southeast 5°.

"A number of rather badly preserved fossils were secured at this locality which have been named as follows by Dr. Ami:—

Halysites catenularia, Linnæus.
Columnaria, sp, with very irregularly disposed horizontal tabulæ.
Zaphrentis, sp.
Streptelasma or *Caninia*, sp.
Rhynchonella, sp.
Murchisonia, two species.
Euomphalus, very large species.
Discosorus, Cf. *D. conoideous*, Hall.

"The above fauna represents the Clinton formation or lower portion of the Niagara.

Piche Point

"On the east side of the lake, from the point south of Chiefs' Island to within less than a quarter of a mile from Piché Point, the shore is occupied by a narrow fringe of the basal conglomerates and sandstones of the Niagara. The coarser beds are of the

boulder conglomerates already described, representing simply a talus of angular and sub-angular fragments detached from the elevations in the immediate vicinity of the exposures, consolidated together by a finer grained arenaceous cement of a yellowish colour, in which are also imbedded fragments of corals and orthoceratites.

"This boulder conglomerate passes upward into a fine conglomerate, in turn replaced by a coarse grit, and becoming finally a yellowish, rather friable sandstone. These beds run in long undulating curves, closely following the general outline of the underlying quartzite with a general westerly dip at angles varying from 10° to 15°. The action of the waves has in places caused this to disintegrate very unevenly, leaving a roughly pitted surface. At Piché Point and for some distance north, the Huronian quartzite is left entirely denuded of these deposits.

"In the bay to the south of Piché Point, and between this and Wright's silver mine, there are two small patches of thinly bedded light-yellow arenaceous limestone dipping in a southerly or southwesterly direction 5°; immediately south of Wright's mine is another small patch of similar arenaceous limestone dipping southwest 9°.

"On the east shore of the lake, nearly opposite Bryson island, there are two more small patches of the arenaceous limestone exposed at the shore wrapping round the hummocks of Huronian quartzite and dipping in a southerly or southwesterly direction 5°. None of these small patches of limestone contained any visible fossil remains.

Mann Island and Dawson Point

"On Burnt or Mann island, as also on the two smaller islands between this and Bryson island (Oster and Brisseau islands), as well as on the high promontory (Dawson point) separating Wabis and Sutton bays in the northern part of the lake, are exposed the limestones and shales that represent the deep-water deposits of this period. The limestone is of a pale yellow or cream colour, weathering whitish, and varies in thickness from a few inches up to two feet or over. Some of the beds are very fine-grained and of rather even texture, and it is possible that some parts may prove to be sufficiently uniform for use as lithographic stone. As a building stone it is of excellent quality. These limestones, on the north shore of the lake at Dawson point dip a little south of west at an angle of between one and two degrees, rising into cliffs of over a hundred feet in height on the west side of Sutton bay, and forming a somewhat elevated rocky plateau with a gentle westerly slope, corresponding mainly with the angle of dip towards Wabis bay. The east shore of Mann island presents a somewhat similar, though much lower escarpment, while the western shore is a gently shelving beach, which at low water reveals considerable areas of the almost horizontal limestones. Some of the beds contain a considerable proportion of silica of a cherty character, and all the fossils are more or less silicified. The action of the weather causes them to stand out in relief and often displays their minute structures perfectly. A large collection of these fossils was made along the western shore of Mann island, comprising the following forms as determined by Dr. Ami and Mr. L. M. Lambe:——

Bythotrephis (Chrondrites) gracilis, Hall.
Bythotrephis, Cf. *B. palmata*, Hall.
Clathrodictum fastigiatum, Nicholson.
Cyathophyllum articulatum, Wahlenberg.
Zaphrentis Stokesi, Milne-Edwards and Haime.
Favosites Gothlandica, Lamarck.
Alveolites Niagarensis, Rominger (non Nicholson).
Cladopora crassa, Rominger.
Syringopora verticillata, Goldfuss.
Syringopora Bifurcata, Lonsdale.
Halysites catenularia, Linnæus.
Halysites compacta, Rominger.
Lyellia affinis, Billings.
Lyellia Americana, Milne-Edwards and Haime.

Thysanocrinus liliiformis. Hall.
Dendrocrinus longidactylus. Hall.
Taxocrinus, n. sp.
Lichenalia concentrica. Hall.
Phænopora expansa. Hall.
Trematopora, sp.
Orthis (Dalmanella) elegantula. Dalman.
Orthis calligramma, Dalman.
Platystrophia biforata. var. *lynx*, Eichwald.
Strophomenoid shell, type of *Rafinesquina*.
Strophcodonta. sp. (? n. sp.)
Leptæna rhomboidalis. Wahlenberg.
Atrypa reticularis. Linnæus.
Atrypa intermedia. Hall.
Trematospira. sp.
Pentamerus oblongus. Sowerby.
Euomphalus alatus. Hisinger.
Murchisonia. sp.
Murchisonia, *subulata*. Hall.
Discosorus conoideus. Hall.
Diseosorus gracilis. ? Foord.
Orthoceras, sp.
Orthoceras, sp. Cf. *O. virgulatum*, Hall.
Orthoceras, Cf. *O. Cadmus*. Billings. Cf. *sub-cancellatum*, Hall.
Actinoceras vertebratum. Hall. *A. Bachi*. Stokes.
Calymene Niagarensis. Hall. Probably identical with *Calymene*.
Blumenbachii. Brongniart.
Beyrichia. sp. Cf, *B. lata*. Hall."

APPENDIX II.

PROFILE

FROM

Toronto to the Archean Paleozoic boundary on Hudson Bay Slope.

TO ACCOMPANY

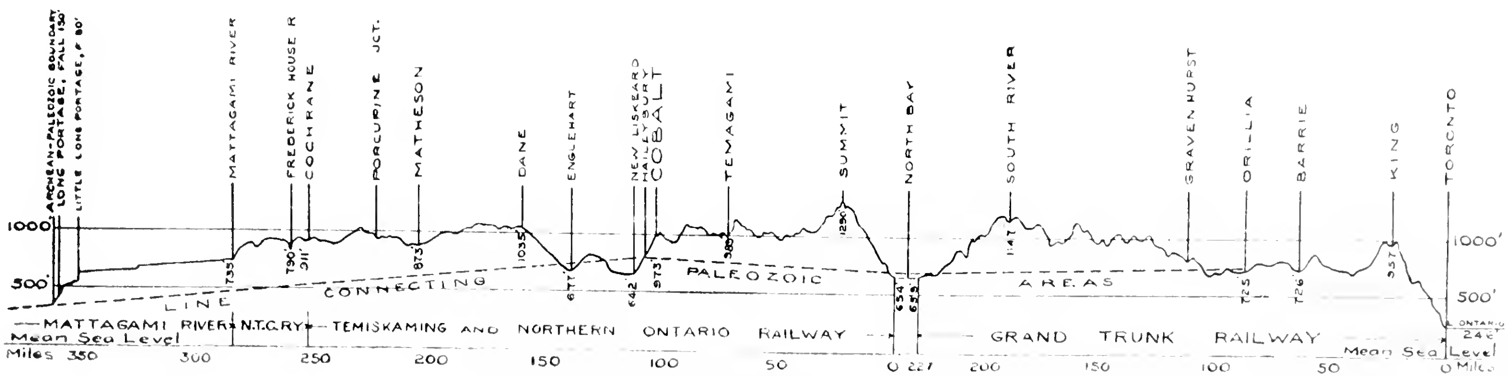
Part II. of the Nineteenth Report of the Bureau of Mines, Ontario

1911

WILLET G. MILLER, Provincial Geologist   W. R. ROGERS, Topographer

Sources of Information:—"Attitudes in Canada" by Jas. White.
Profiles of the Grand Trunk, Temiskaming and Northern Ontario, and National Transcontinental Railways.
The section showing the Mattagami River is approximate, having been compiled from various sources, and some of the data is conflicting.

Notes: The profile connects four Paleozoic areas. The northern edge of the Lake Ontario area is in the vicinity of Orillia. Smaller areas or outliers are found at Lake Nipissing and at Lake Temiskaming. The north end of the profile shows the location of the southern edge of the James Bay area. With the exception of the outliers at Lakes Nipissing and Temiskaming the profile crosses pre-Cambrian areas. The profile is instructive in that it brings out the plain-like character of the pre-Cambrian region.



Scale: Horizontal 80 miles = 1 inch
Vertical 1600 feet = 1 inch.

APPENDIX III.

THE EARLY HISTORY OF THE COBALT INDUSTRY IN SAXONY

Translated by G. R. Mickle

"Is there anything whereof it may be said, See, this is new? it hath been already of old time which was before us."—Ecclesiastes.

Introduction

The following translation of portions of W. Bruchmuller's work (now unfortunately out of print) on the early history of cobalt mining and the manufacture of blue color in Saxony will perhaps interest those engaged in the cobalt industry to-day*. In the main the problems ahead of the miners of that metal at the present time are the same as they were over three hundred years ago.

The cobalt production marked a second period of mining activity in the district in question. The first was characterized by a feverish excitement and activity and a comparatively short life. Silver was the only metal sought at first and the veins were sometimes fabulously rich. Two systems of veins were known—the silver with barite as gangue mineral and the cobalt veins with quartz.

The exact time when mining started in the cobalt region is not known, but the first important discovery of silver ore was made at Schneeberg in 1470, and the growth of the industry was phenomenal; by 1474 there were 176 producing mines. The most famous was the St. George at Schneeberg where veins of different formations joined and where one enormous block weighing 20 tons, described as 6 feet wide and 12 feet high, consisting of native silver, argentite, ruby silver and the chloride of silver was found. Records mention a banquet given underground by the Duke of Saxony using this block or nugget as a table.

Silver mining flourished for 25 years or more and then began to die down. Some of the veins had a length of about 2,500 feet and were followed in depth about 1,000 feet. These were, however, extreme limits.

In the case of the essentially cobalt veins (which carried some silver) there was an extraordinary massing or crowding together. In an area of less than four square miles 150 productive veins were found. After the invention of cobalt blue, mining flourished again.‡ It is with this second period of activity that Bruchmueller's work is concerned.

It is evident from the translation given below that an immense amount of searching into old archives was involved in the preparation of this work.

FORMER PRODUCTION OF COBALT GREATER THAN AT PRESENT

One thing that is striking in reading the accounts of the cobalt industry of one or two hundred years ago is that at that time the amount of cobalt produced was probably greater than it is now. A work by Friedrich Kapff, published in 1792, gives details of the state of the industry at that time. Kapff was employed by the Finance Minister of Prussia to make a report on the works in Querbach in Silesia particularly, and he included also a description of all theother works existing at that time, which he had visited. These amounted in number to twenty-three, not including the works of Holland. One French works is included and also one in Norway. Unfortunately the amount of cobalt oxide is not given, but the amount of smalt or blue color, the manufacture of which is described below, is mentioned. In sixteen out of twenty-three cases such information is given that the amount can be fairly closely estimated, and it comes to about

*Der Kobaltbergbau und die Blaufarbenwerke in Sachsen bis Zum Jahre 1653 von W. Bruchmueller, 1897.

†Stelzner-Bergeat. Erzlagerstaetten.

in pre-historic times.

‡This was really a re-invention, as cobalt is said to have been used for staining glass

2,500 tons, so that if the other seven works were included it would probably amount to over 3,000 tons. Of this amount about one-half was produced in the Saxon works which were much the most important. The works were of course small when compared with smelting works as they exist now. For instance, in the description of one of the best of the smelting works the external dimensions were 48 feet × 34 feet and 14 feet high, and this building included a room for the foreman. The mechanical building, where the stamp batteries were for pulverizing, was 114 feet, 30 feet wide, and contained eight stamps, a grinding mill, storeroom and drying rooms for drying the quartz. The works were built always on some stream which furnished the water power and were worked by over-shot wheels.

With regard to the smelters in Holland no details are given of amounts. It is known, however, that the Dutch refineries supplied the Irish trade almost entirely, and also consumed a large amount themselves in the linen industry and in the manufacture of litmus.

In all the trade, including the amount made in Holland, the total manufacture of color would probably be from four to five thousand tons, and this color might contain anything from three to, say, fifteen per cent. of cobalt, therefore probably three to four hundred tons of cobalt were actually manufactured in Europe over one hundred years ago, so that in spite of the enormous increase in the consumption of all the other metals, owing to the expansion of industries, the consumption of cobalt has probably actually decreased. This is due no doubt to the fact that it has been replaced in the linen trade by vegetable coloring matter.

BEGINNING OF COBALT INDUSTRY

The beginning of cobalt mining and the knowledge of the use of cobalt in Saxony are wrapped in obscurity. The discoverer of the blue color is said to have been a Frenchman, Peter Weidenhammer, who settled in Schneeberg in 1520 and made a blue color which he sold in Venice for 25 thalers* a hundredweight (112 lbs.). Christian Schuerer is said to have improved the invention of blue color. He had a glass works at Neudeck, and it is believed that there for the first time a blue color was made out of the cobalt from Schneeberg by fusing and the addition of pearl ash or potassium carbonate. It is said that this color was sent to Nueremberg and was there seen by the Dutch, who then went themselves to Neudeck and persuaded Schuerer to go with them to Madgeburg to make cobalt blue for them. Afterwards, when they had learnt Schuerer's secret, they sent him home again, where he started a small color mill. A hundredweight of this color at that time cost 7½ thalers. It sold in Holland for 50 or 60 gulden.† The Dutch are said to have immediately built eight color works and to have imported the necessary cobalt from Schneeberg. This blue color was made by taking the cobalt ore, in this case, smaltite, which contained some bismuth, and melting the bismuth out by gentle heating; then it was stamped and roasted in reverbatory furnaces. It was important that the roasting or oxidation should be as complete as possible. The result of this process was the cobalt oxide, known in the trade as safflor, a grayish brown powder. In order to make cobalt blue out of the oxide it is mixed with potassium carbonate (pearl ash) and white quartz and fused, then dipped out with iron spoons into a large vat, in which cold water runs continuously. By this means the blue colored glass attained its deep blue tint and became so brittle that it could be crushed and ground.‡ This crushed and ground material is then sifted, washed and finally graded through very fine sieves. By means of the washing the soluble constituents are removed, and the different colors known to the trade are produced, according to the fineness of the material.

We see, therefore, that in the beginning the production of the cobalt oxide in Schneeberg was not in the hands of large operators, but the small works treated their own cobalt and sold it to dealers who came to Schneeberg. The oxide was then sent to foreign countries.

* Thaler=about 75 cents.
†Gulden=about 45 cents.
‡The blue color or smalt usually contains about 6 per cent. cobalt.

Cobalt Works in 1568

In the knowledge of the art of color-making they seem to have made rather rapid progress, for about the end of the sixteenth century they had begun to make the blue color themselves. The first one to make this was Christopher Stahl, who put up a small smelting works at Schneeberg in 1568, also some mills, melting furnaces and color works, in which he made a blue color for artists. Nothing is known about the extent of his works, but it could not have been great, as Stahl's undertaking is only mentioned incidentally, and the production of colors for artists could naturally not be carried out on a large scale. These works did not last long. They were swept away by flood in 1573. After Stahl's death an attempt was made to carry on the color trade on a larger scale, and according to the spirit of the times, this undertaking must first be protected against competition by a decree on the part of the State, but in spite of the energy and business ability and large capital of the two engaged in the undertaking, it failed. The two in question were Hans Harrer and Hans Jenitz. They went to the Prince in 1575 requesting a concession to erect a color works and to allow them the exclusive right for ten years to purchase cobalt ore in Schneeberg. They stated that they had noticed for fourteen years how the oxide which was prepared in Schneeberg and the vicinity was bought up by agents of foreign merchants and sent out of the country to Nuremberg and from there to Italy and Venice and other places. Out of this oxide blue color was made and sold at a high price. By means of laborious experiments and at a large expense they had arrived at the secret of the preparation of the blue color, and they were now willing to put up a works but they were afraid that very soon others would be engaged in the preparation of colors, and therefore they requested the concession mentioned above. Stahl's works were not mentioned by them at all, and from this we see that his plant cannot have been large.

First Monopoly Granted in 1575

This concession was granted them by Prince August in 1575. According to it Harrer and Jenitz could erect the color works and they alone had the privilege for the next ten years to buy cobalt oxide in Schneeberg, and they could work it up and deal with it as they wished. They had to pay, however, the cobalt mines the same price which they had got for the ores from the foreign dealers. No one during these ten years could engage in the preparation of color without their consent, neither could he buy the ore or the oxide and ship it out of the country.

This undertaking, however, did not fulfil the expectations placed upon it. Schneeberg was, of course, the principal place of production for the oxide, which, as before, was chiefly prepared by the works themselves, and then sold to Harrer and Jenitz. The color exchange was in Dresden, but in spite of numerous efforts, the disposal of the colors presented great difficulties. Moreover, contrary to the royal concession many engaged in the preparation of color in Schneeberg, and bought up the oxide and sold to competitors in Nuremberg, who probably also worked up Bohemian cobalt and brought it on the market. A letter of this period, namely, 1579, from Hans Harrer to foreign merchants shows us the state of affairs and how Harrer exerted himself to find a market for his product. Harrer complains that he had spent a great deal of money for the purchase of the oxide and the preparation of the color, but in spite of all that he could not find a market for it. He could only deal in the matter at a loss. Not long before, he stated, he had sent some of his color to Lisbon, but the merchants there had done very little with it and finally it was left unsold. He (Harrer) had quite a stock on hand which he wanted to get rid of, and he therefore asks for the addresses of those to whom he might send it.

Troubles of the Cobalt Buyers

In 1579 Harrer and Jenitz complained to the Prince. They stated that in spite of the concession which had been granted them there were about twenty others in Schneeberg who were engaged in buying up cobalt and making it into color, and that

these others were putting everything into barrels, whether it was good or bad, and trying to sell it for good color, and therefore it had come to this that during the four years of their monopoly they had put several thousand gulden into the undertaking, and had not been able to sell most of the color or oxide which they had prepared. Moreover, several of the inhabitants of Schneeberg, contrary to their concession, had demanded a higher price for their oxide, and when this was not granted they had taken the color out secretly at night and even sometimes had packed it out openly on their backs. Harrer and Jenitz, therefore, begged for a renewal of their monopoly and an extension for four years more, and a sharper decree against the smuggling of cobalt and cobalt oxide.

The Prince granted this request and renewed the concession till 1589, according to it the contractors alone had the right to buy bismuth and cobalt and the oxide. The works might, it is true, work up their cobalt ore themselves to oxide, but then they must sell it to Harrer and Jenitz for 10 groschen* a hundredweight. Selling to others would be punished with a fine of 200 thalers and confiscation of the goods, which would belong to Harrer and Jenitz. In spite of this decree the undertaking was not a success, and after the death of Jenitz in 1589 (Harrer had died in 1580) and the expiry of the concession in the same year, it was not renewed, so that the first attempt to organize the Schneeberg cobalt and color trade and to make the blue color in Saxony themselves, was a failure.

Change in Industrial Conditions

About this time there was a change in the political organization of the country. Every undertaking of any size required a concession from the Prince, just as we saw in the case of mining, and the ideas of the rights of the Princes gradually changed. These conditions made their influence felt on the cobalt mining of Schneeberg, and rendered it possible to bring in considerable amounts of foreign capital because the Princes, who were at this time almost always in need of money, gave concessions for the exploiting of their mining privileges in consideration of certain loans from foreign traders. This was acceptable to the foreign traders, as they had thereby the only security for their money.

Stealing of Ore in 1603

In the year 1603 we hear for the first time of a more strict supervision on the part of the Prince over the production of oxide. In this year the mining office complained to the Prince that there were people in Schneeberg who were engaged in making the oxide, but did not have any cobalt or bismuth mines. The Prince decreed, therefore, that for the future no one should be allowed to buy cobalt or bismuth or sell it before it had been accepted by the mining office and determined whether it came fresh from the mine or had been taken from some dump.

Export Tax

Shortly after this also the Prince put a tax on the Dutch merchants for the cobalt that was bought in Schneeberg, and ordered a strict supervision of the export. In the decree in question it was stated that merchants from Holland in the last quarter of the year had bought over four thousand hundredweight of oxide in order to take it to Holland, England and Spain—from this the Prince did not receive any taxes. Out of the tax of one-twentieth very little came in, and from this the Prince had always to keep the principal adits in order and therefore for every task of oxide that was sold a gulden must be paid as tax. This tax would fall on the foreigner, and they would not evade it because they had a good market for their wares; all colors, for the purpose of collecting this tax, must be weighed by an official in Schneeberg, and recorded. Any evasion of the tax would be punished with a fine of 500 florins, and confiscation

*Groschen=about 2½c.

of the goods. Every cask must be printed with a certain mark, and all casks without this mark were to be expropriated. In the same year one Berckau from Joachimsthal came to the Prince with a proposition that the Prince should take the sale of the color into his own hands, as according to Berckau every year great quantities of color and cobalt were sent from Schneeberg to Hamburg and Holland, and from this the Prince only received a very small tribute, but everything for the manufacture of color was found in Saxony, and he, Berckau would guarantee to make good color glass out of the Schneeberg cobalt for half the price which it cost them in Holland and Hamburg. Moreover he said the Hollanders would far rather buy the glass than the raw oxide. If the Prince would take the sale of the color in his own hands he and an associate would take charge of it and produce yearly two or three thousand hundredweight of color glass. He gave two calculations as to the cost of color in Saxony and Holland as a basis for his proposition. The calculation as to the cost in Saxony was as follows:

	Florins.
100 cwt. of unstamped cobalt ore cost	300
Wood for roasting	9
Two workmen for 14 days	9
Loss 3 cwt.	9

therefore 100 cwt. as exported from here cost 327 florins, and add to this

	Florins.
50 cwt. flux	400
Wood to melt	42
4 workmen for the melting for four weeks at the rate of 2 florins per week per man	36
Other expenses	25

or a total of 830 florins for 100 cwt. He calculated in the same way the cost in Holland at 1,000 florins. Now as a hundredweight sold in Hamburg for 20 florins, therefore the profit was 100 per cent. The Prince should give him an advance of 5,000 florins for his works and they would take charge of it, but they must first take a trip to Holland and England in order to make contracts with the dealers for large amounts. As remuneration they asked 20 per cent. of the profits. The Prince did not consent to this proposition of Berckau's. The result of this proposition and consultations was the royal decree of 1609, in which it was made known that for the future the Prince would buy up all the cobalt made in Schneeberg, which was formerly taken by foreign merchants and sent out of the land. The purchase was to be made through the tithe collector. The works producing cobalt were directed not to sell their cobalt to any one else under a penalty of 500 florins, and all the dealers were forbidden under the same penalty to buy cobalt without the consent of the Prince, or to dispose of their stock on hand either in or outside of the country. The Schneeberg cobalt trade thus became a State undertaking.

SCHNEEBERG COBALT AND OXIDE TRADE AS A STATE UNDERTAKING

The first consequences of the change of the Schneeberg cobalt and oxide trade into a purely State undertaking were decidedly favorable. The stricter organization, and the greater capital which the new management could command, led in the first place to a rise in the price and increase of the sale. This operated in favor of the cobalt miners, even although it must always be kept in mind the money bags of the rulers profited by the change. In the course of time, however, the financial difficulties under which the Princes at that time almost always labored exercised a baneful influence. Their interests were always more and more put in the foreground, and they were willing to let the works get under control of capitalists who were able to make large loans. These concessions would be given for a period of years. It must, however, be acknowledged that, as a last resort, the mining office stepped in on behalf of the cobalt miners and the Prince generally followed the advice of these officials and remedied the most crying evils. Moreover, the terrible industrial crisis began to make its influence felt. This was brought about by the practice of clipping coins and by the Thirty Years' War. These circumstances led to a complete ruin of the Schneeberg cobalt mining and the oxide trade about the period of 1620-30. We will look into these circumstances more in detail shortly, but must first notice the organization of the cobalt and oxide trade as it existed after the conversion of the industry into a purely State undertaking.

Ordinance of 1609

According to the ordinance of the Prince in 1609, the tithe-collector in Schneeberg had to take over all the buying and selling of cobalt and oxide. The first task was to find a buyer for the cobalt purchased from the works and the dealer, Kreifinger, applied to the Prince for a fixed contract. The following agreement was made with him in 1610. It was for a period of six years: All oxide colors which were produced during these six years in Schneeberg and were of good quality were turned over to Kreifinger. He had the power to sell his oxide wherever he wished, but he must first supply the business houses of the Principality with these wares. Kreifinger had two Leipzig merchants as guarantors. The price per hundredweight was six gulden and ten groschen and notice had to be given half a year before expiry of the contract. Kreifinger had to advance the Prince 3,000 florins, and he was to receive back 500 florins per year and the interest. Some alterations were made in this contract afterwards to the effect that the oxide was divided into two classes. These changes were in consequence of complaints on the part of the contractors. They objected especially to the fact that all the oxide that was produced in Schneeberg should be accepted by them, and therefore every year fixed amounts were agreed on. The whole management of this business was left to the tithe-collector. He had to look after the purchase and taxing of all the cobalt ore delivered by the works, then deliver them to the contractors and carry out all the bookkeeping. There were numerous complaints on the part of the works that the tithe-collector estimated their cobalt too low. The bucket of cobalt ore was paid for at the rate of two to three florins, and the hundredweight of oxide three or four florins. This task soon became too great for the tithe-collector. He therefore requested assistance in his work, and a couple of officials were allotted to him. These two officials were to inspect and estimate the cobalt in the presence of the tithe-collector and agents of the contractors, to look after the roasting of the re, visit the stamp mills weekly, weigh out the color for the dealers, and keep strict account of all color that was made.

An attempt was made to induce the Prince to cancel the contract with Kreifinger. He was accused of being a swindler, who had already been in jail. At the same time proposals were made to make the color in Saxony. In spite of these objections the Prince stood by the contract, and even renewed it for six years more. According to this later contract the Prince had to deliver yearly 3,500 hundredweight of oxide, 3,000 at 8 florins and 500 of inferior quality at 6 florins. Kreifinger, in consideration of this, made the Prince a further loan of 4,000 florins. These advances on the part of the contractors to the Prince were characteristic of all the concessions.

Troubles of the Miners

A few years after this, namely, in 1616, the cobalt miners petitioned for a remission of the tax on the ore and for a higher price for their cobalt, as mining was getting more expensive all the time, and the ore scarcer, and prices for necessary articles were always rising. The tithe-collector suggested an increase of half a florin on the bucket.

In 1617 the following ordinance was made:

1. All the cobalt ore must be inspected by the officials before it is rated and taken to the ore house in order to determine from which mine it came and to see whether good and inferior ore were not mixed together. For this inspection the mines had to pay each time two groschen. The previous taxes were maintained.

2. No robbing of the mine was to be practised.

3. No miner was to go underground more than two shifts in the day.

4. All the cobalt purchased from the works was to be kept separate and roasted by itself in order that the tithe-collector and the superintendent of the cobalt could settle correctly with the different works, and in order that the cullings-out could be replaced by the different works.

5. The assayer had to take a sample from each cask of oxide, and this was to be kept in the office.

6. No cobalt ore was to be stamped either by night or on holidays.

7. Two buckets were to be kept and filled with ore by the works, one of which the tithe-collector was to receive and the other the mining office.

8. The officials had to inspect the color works weekly, and the ore-dressing plants, and no one had any right to enter the stamp mills without permission.

9. Every cask of color was to be weighed and stamped with the Prince's trade mark. The color was to be sold by the hundredweight to the merchants in Holland.

Unfortunately, however, these rules were not observed, and we see that shortly afterwards the works were complaining over the tithe-collector, Roehling's, practice of culling out. The cobalt that was delivered by the works was not kept separate, they stated, but all mixed together, and then the works were compelled often to replace more ore than was culled out than they had sent in the first place—for instance, one mine which had delivered 53 buckets of cobalt was ordered to replace 64 buckets, and moreover they said this ostensibly culled ore, which was often better than the cobalt that was accepted, was not sent back to them, but was taken sixty miles and farther sometimes—they would like to know why. They said that the tithe-collector was always in debt to the works, so that they were compelled, in order to carry on their mines, to borrow capital at high rates of interest. Therefore they requested that Roehling be ordered to cull out the ore from each work separately, and to give back what was culled out in order that they could pay off their workmen properly, and they also asked that the tithe-collector should pay them in full every half year, or if not, that the Prince should allow the works, after this contract was run out, to work up their cobalt to oxide themselves and sell it as they might. They offered to give the Prince, if the tax of one-twentieth was repealed, for every hundredweight of oxide one florin. They stated this would bring in more than came from the contracts now. The Prince promised to look into the matter of the excessive culling by the tithe-collector, and to give them an answer about this open dealing after the contract expired. In the same year the works made another complaint about their being in arrears with their payments. They stated that they were no longer in a position to pay their workmen, and they had to keep on borrowing money at high rates of interest.

Coin Clippers Period

We come now to the time of the Thirty Years' War and to the general money crisis in Germany, which is known as the time of the Coin Clippers. The consequences of the war were noticed in Schneeberg after a few years, but the tremendous money crisis was felt at once. In Germany for some time there had been excessive clipping of coins going on, and in consequence of this currency of full value was vanishing, and the

country was flooded with depreciated money, thereby bringing about a tremendous increase in the price of all articles. This money crisis was all the worse because it coincided with the Thirty Years' War, by which trade was crippled everywhere. In consequence of these two circumstances the production fell greatly, from over 8,000 buckets in 1620 to about 2,000 in 1639.

The cobalt miners regarded the contract which the Prince had forced on them as the sole cause of their desperate position. They were no more able to recognize the true cause of the industrial crisis than their contemporaries. Their object, therefore, was to have this contract cancelled and to obtain unrestricted trading in their cobalt and oxide without the intervention of the tithe office and foreign dealers. They therefore asked in 1619 for the granting of open dealing in cobalt, and the Prince told them that after the contract ran out in 1620 he would give them an answer. The Prince was, on his part, too much dependent on the support of these foreign dealers, as it was only with their large capital that he was able to undertake the extensive business involved, and the contractors, on their part, were quite content to have the concession as a guarantee for their debt. He therefore could not entertain the wishes of the miners.

The Prince renewed the contract with the Dutch for six years, but it was finally cancelled, as the contractors only wished to take yearly 3,500 hundredweight as before, while the Prince demanded the purchase of a larger quantity. In spite of this the Prince would not grant open dealing, but made another contract with some Leipzig merchants and others. The contract was for twelve years. The Prince agreed to deliver them yearly 6,000 hundredweight, and the contractors could deal with these either at home or in foreign markets, but they must first supply the dealers of Saxony. If the contractors could not get rid of the color afterwards they could keep it in Schneeberg in some of the offices, and in the meantime no one else should be allowed to deal in color, and the Prince would give a patent against cobalt smuggling. On their side the contractors must agree to take the 6,000 hundredweight yearly, even if war broke out, and stopped trade, and they must pay in cash 5,000 cwts. at 8 florins, and 1,000 cwt. of inferior quality at 6 florins. Payment must be made in good French money.

Loans from Contractors to Prince

In the autumn of that same year the Prince applied to the contractors for a large loan. He explained to them that he required 50,000 florins for a very important matter, and requested them to advance this money. They declared that it was at the moment impossible for them, but they would manage to do it in the course of six weeks, advancing the money at seven per cent. Some time afterwards they said that they were ready to advance the 50,000 florins if the oxide trade and the purchase of the cobalt was made hereditary and irrevocable to them, and that they should buy the cobalt by their own agents and work it up to oxide themselves without the royal tithe-collector having anything at all to do with it. For this privilege they would pay the Prince 4,000 gulden yearly. The Prince agreed to this unheard-of demand without hesitation. The contractors were to make the payment and the tithe-collector to be notified of the fact.

Intervention of Mining Office

This doubtful step was not carried out however, as the mining office took a hand in the affair and explained to the Prince that this proposal was contrary to all mining rights; that the miners would leave, and then he would lose the 4,000 florins which he got from the contractors, while the cobalt mining had brought in the Prince yearly up to the present time about 6,000 florins. This concession was never formally withdrawn, but is never mentioned again, and matters remained as they were, the contractors lending the Prince 17,000 florins, which the Prince set down to the credit of the works. In the next year the works sent an urgent request to the Prince to pay them for their cobalt that was delivered, that there was 17,000 florins overdue from the tithe-collector, and they further asked for payment in good coin of the land, and not in copper coins from Brunswick, which they could not get rid of. They stated that all necessities

and appliances were advancing at a terrible rate, the price being about three times what it was before, so that a great many had to leave on account of the expensive living, and finally they expressed a desire for open dealing again, and requested an extra payment for the cobalt. The mining officials agreed, or gave a favorable report on this petition, and suggested that they be repaid the 17,000 florins and get half a florin more per bucket for their ore. This was done by the Prince. The contractors, on the other hand, were not by any means satisfied. They had expected a greater profit for their undertaking than it really gave, and thty complained continually about cobalt smuggling, further, they objected to the tithe-collector at Schneeberg,—that he delivered them oxide that was no good. The Prince therefore ordered a strict inspction by the mining office, as these complaints had become too frequent. The remonstrances, however, continued till finally the Prince ordered an investigation. In consequence of this investigation the Prince took away the control of the outside works entirely from the tithe-collector, and put them in charge of a new officer. This concession did not satisfy the contractors; in the meantime, in order to get rid of the contract, they had made an agreement with one Brandenstein, and in consequence of this they stated that they had everywhere found opposition, and reverses with their contract, and they feared great loss, if not complete ruin. Therefore they requested the Prince to hand over their contract to Carl Brandenstein.

The Prince was heavily in debt to Brandenstein, who was a money-lender of the worst kind. He had lent 22,000 florins of depreciated money to the tithe office, and probably he expected to recoup himself with the oxide trade of Schneeberg. He did not succeed in this, however, as his inconsiderate treatment of the miners overshot the mark, so that he had to abandon the contracts. He had asked the Prince for the most complete and untrammelled powers in the direction of the business for twelve years. According to the contract, Brandenstein would take over the purchase and the preparation of oxide. All the directors of the color works and all the employees of the Prince, except the mining officials in the mining office and tax collectors, were to be put under the direction of Brandenstein, and he had the power to dismiss them or fill their places, after notifying the mining office. The new officials would then be engaged by the Prince and turned over to Brandenstein, who was to pay their salary. The cobalt ore was to be paid only in good coin, but the works had to deliver good, pure material. Material that was worth less than 3 florins need not be paid for at all. Any ore that was not good would be put aside and could not be sold. All good cobalt Brandenstein was forced to accept, but he need not pay for it at a higher rate than five florins, and he must pay in good coin. All the color works and stamp works which were in bad repair Brandenstein was to take over and he would be recouped for the expense of repair after the expiry of the contract. He was to receive wood out of the Prince's forest at the usual price and in addition to the stamp work he might build a new cobalt works, the cost of which would be refunded to him. He should have the stamp works belonging to the tithe office as long as he wished for one gulden weekly rent; in consideration of his previous advances the whole stock of oxide, etc., and 16,900 buckets of cobalt were handed over to him. He could make this up to color and sell it wherever he wished, and in consideration of this he had to pay the works the money that was due, but they had to first replace the ore that had been culled out with good cobalt. After the expiry of the contract Brandenstein or his heirs had a prior right to a renewal of the contract. If the supply of cobalt ore failed the contract would be cancelled and Brandenstein had to see that the various taxes were all paid.

Disputes between Miners and Contractors

We see that by this means the Prince had handed over the trade in oxide, which had been very profitable to the Treasury, to Brandenstein for a period of twelve years without any further consideration except that the Prince was free from the responsibility of paying his debts to the works. Immediately after the signing of this contract a bitter quarrel began between Brandenstein and the works. They demanded payment

of the balance of over 30,000 florins which was due them for cobalt which they had delivered. Brandenstein put every obstacle in the way; he demanded the replacing of the ore which was culled out, and stated that the stock on hand was a great deal smaller than was represented to him at the time when the contract was made. The works on their part, objected to the excessive culling. They would have to close down their mines and send off all their men, who already lived in the most wretched state of poverty. They stated some were even dying of hunger. Their creditors were threatening to evict them from their mines, and the adit was in danger of caving in, as they had no means to keep it in order, and furthermore they complained especially about a wilful underrating of their cobalt and of the low price. In spite of the efforts of the higher officials of the office to induce Brandenstein to accept some of the lower grade cobalt and to pay up the outstanding amounts of the works, he obstinately stuck by the letter of the contract, and complained that he was losing by it. The works did not let the matter rest. In spite of a sharp notice from the Prince about their inopportune grumbling they continued to send complaint after complaint, always about the same points, and with the same conclusion, namely, that they should be allowed open dealing for their cobalt. Brandenstein finally gave way to this uproar raised by the works, which was backed up in the most essential points by the officials in the mining office. He therefore voluntarily cancelled his contract with the Prince and the Prince gave permission to the works to make up the cobalt to oxide themselves, and to deal with it as they wished, but they had to pay the regular taxes, and in addition to that one florin for every bucket of cobalt made up to oxide. Smuggling in cobalt would be punished by a fine of 500 gulden.

Open Dealing Not a Success

The cobalt works had reached the desired goal, and they hoped that with that all their difficulties would be at an end. But very soon the opposite became evident, and although the management of the State might have been a great deal to blame for what had happened in the last few years, it was not the only reason for the decline of the Schneeberg cobalt mining. It was rather dependent on the general industrial and political crisis under which all trade and industry languished, and the general purchasing power of the public greatly diminished. This was especially noticeable in an article which was not absolutely necessary, such as the color, and in times like this it was the small works and those with less capital which necessarily suffered most. We hear, therefore, a few weeks after open dealing had been allowed, strong complaints on the part of the works. They stated that in addition to the tax they should not be required to pay one florin for every bucket of cobalt,—that Brandenstein had ruined the whole business and no human being was willing to buy any color from them. The cost of mining a bucket of cobalt was two or three florins, and if the expenses were so great they would have to discharge their miners, and therefore the Prince should remit the one florin on the bucket of cobalt. The Prince granted this request in part, and an inspection was ordered of all the works by the tithe-collector, and that the adits should be kept in repair where there was any danger of a cave-in or other damage, and they were further to see that the barren rock did not remain in the adit, but should be brought out to the surface. For the purpose of collecting a tax they should inspect all the mines which were producing every two to four weeks, and be present when some of the ore was hoisted, and should cull the cobalt in proper manner and measure it up. The works were not satisfied with this. The Prince pointed out that the office, the mining officials and the works had made representations about excessive taxation, and that the works had said they were ready to pay these taxes if they got open dealing, and that they stated they would find enough buyers who would take their cobalt at ten florins which they were forced to sell at five. Now they said the very opposite. They were to blame themselves. In spite of this he said that he was willing in the future to take the tax of one florin a bucket and remit the mining taxes.

As soon as an opportunity offered the Prince made one more effort to close a new contract. Two men offered to negotiate: one was the merchant, Hans Friese, and the

other was from Frankfort, Daniel de Briers. Both declared that they had bought a great quantity of oxide, but the business had not succeeded, as in the previous years a great deal of very bad material had been made, still they were willing to go on with the venture if a monopoly was given for from one to three years. The Prince seized this opportunity immediately and made a contract without consulting the Schneeberg cobalt works. It was for six years. According to this the two contractors were to take yearly from Schneeberg and Neustadtlein 3,000 buckets of cobalt. The payment should be made according to four grades. The No. 4 grade was to be considered as absolutely worthless, and the first three grades were to be paid respectively with 3, 2½ and 1½ reichstaler. The samples were to be kept in Schneeberg and the cobalt was to be taxed according to them. The cobalt, as soon as it was taxed, was to be delivered to the two contractors, who could make oxide of it and deal with it at home or abroad, as they liked. The payment for cobalt was to be made to the works immediately by the contractors in cash without any deductions, that is, neither the Prince nor the tithe office had anything to do with it as formerly. The latter had nothing more to do with the trade, but merely inspected it through the mining office. Moreover, the contractors were to take the cobalt ore which was paid in to the Prince as mining taxes by the works, and also that which was mined in his own mines, at the price of three florins a bucket. At first the contractors were not to export their cobalt and oxide from Schneeberg, in order that the business might recover its reputation again, and all dealing in oxide and cobalt was strictly forbidden to all other persons during this period of six years, but in consideration of this the contractors were bound to take yearly 3,000 buckets, even if war broke out and stopped trade, and if more than 3,000 buckets were mined in one year the excess would be kept for the next year. For this privilege the contractors were to pay yearly 1,000 thalers into the Prince's exchequer, making it in two equal payments, and also pay rent for the works belonging to the Prince which they took over. If the contractors, after the six years, did not wish to renew the contract, they must give a half-year's notice; on the other hand, if they wished to go on they would have the refusal over others.

Contract versus Open Dealing

This contract was submitted to the works, who immediately opposed it, as they declared that it would mean the certain ruin of the whole mining industry. They straightway came to the Prince with a petition about the contract, and to request the retention of open dealing, and they especially complained of the small quantity of cobalt which was to be bought, namely, 3,000 buckets, and of the low price, stating that, under these conditions, they were doomed. They begged, therefore, to have the contract cancelled, and to stick to open dealing. They promised to pay the tax most punctually, and to abstain from any smuggling on their part. In order to meet the works somewhat in this respect the two contractors stated in writing that although they were not, under the existing circumstances, in a position to take more than 3,000 buckets, nor to pay any more for it, they would be willing, if the conditions improved, to buy a greater quantity of cobalt and pay a little higher price. This declaration on the part of the contractors, which was not really of any value, did not remove the opposition of the works, but it had the effect that the works now divided into two parties,—one which declared that they would like the contract provided there was a greater quantity bought, and the price were a little higher, while the other party still opposed the contract. The party which was irreconcilably opposed to the contract persisted that if they got open dealing they would give the Prince, instead of the tax of one-twentieth, every tenth bucket, while the other party stated that this offer could not be accepted, and wished for a fixed contract, however, with the conditions mentioned above. Negotiations in this matter dragged on for some time. The contractors finally agreed to take 4,000 buckets annually, but stated that an increase in the price was impossible at present. The mining office stated that the prices offered to the works by the contractors were not reasonable, as the costs in mining were too high. However, offers

and counter-offers were made, and as a final result the Prince asked for a vote from the works of "contract" or "open-dealing." All the works which were producing ore must state in writing whether they were for a contract or for open-dealing. The result was that 30 persons, representing 87 mines, voted for the contract, and 43 persons, representing 132 mines, voted for the open dealing. In consequence of this majority for open dealing the Prince decreed that the contract was cancelled and permitted open dealing again, with the condition that every tenth bucket of good pure cobbed cobalt ore should be paid into the Treasury, and in addition to this some other taxes, which could be paid in money or cobalt. Those of the works which had received advances from the contractors, or had ore to their credit, should settle the matter with them.

Crisis in the Industry and Effect of War

We come now to the saddest time for Schneeberg cobalt mining. In 1629 the works requested, instead of every tenth bucket, that they should give every twentieth, as they could not get ready cash for their cobalt no matter how cheap they were willing to sell it. This request was repeated in 1632, and at the same time they petitioned for the establishment again of a fixed contract. This, however, considering the bad position of all commercial and political matters, was an impossibility, especially as all the foreign contractors had had bad experiences with their contracts, and were not willing to bind themselves for any length of time. A good idea is given of the conditions and the position of the Schneeberg cobalt mining at this time in a report of the chief official of the mining office in the year 1631. According to him the works since about 1628 had found almost no sale for their oxide because the Dutch had withdrawn entirely from this trade, and they were the ones that had bought up most of the oxide before. Moreover, the war had been spreading all the time, so that all the passes in the mountains were guarded, and all trade was blocked. The works had sought to sell their goods themselves, but they had to dispose of them at a very low price, and at a loss. Sometimes they were not paid for in cash, but in goods, which they could not sell again without a loss, and they had been compelled to pay thir workmen in the mines with cobalt, which they had to sell dirt cheap in Bohemia in order not to die of hunger. It was true that a decree had been made that the workmen were to be paid with money, but there was so little of it in the country that they were afraid that if this decree was observed the mining must be stopped altogether. In addition to this misfortune it seems that about this time Schneeberg suffered directly in the war. In 1632 the Croatians swept down on Schneeberg, took the town and sacked it and ruined many of the mines. At that time the population of Schneeberg was only about 2,000, whereas it had been over 3,000 in the year 1600. In consequence of the lack of money they had neglected to carry on the necessary repairs in the adits, and as a result many of the mines were flooded. The deepest adit caved in about that time, and they were not able to mine any more in consequence of an inrush of water, and the production of cobalt fell off. It is believed that shortly after this there was not a single mine in Schneeberg which made any profit, as at the very most they could only get about 25 groschen for a bucket of ore, while the mining of it cost a florin or more, and in addition to that they had to pay some tax. The only exceptions to this were three mines, which made a little because they had some bismuth.

THE PROSPEROUS TIME FOR THE SAXON BLUE COLOR WORKS

After the year 1628, instead of a fixed contract the cobalt works were allowed to deal with their ores as they wished, without improving the position of affairs at all. We have seen, moreover, that the conditions for mining just at this very time were exceptionally bad. The production of the mines had sunk considerably, and did not begin to increase until after the forties. This was brought about, as we saw, by the depreciation of the coinage. That and the blocking of all trade with foreign countries because of the war, and the other devastations which the war brought with it, had brought the Schneeberg mining into a desperate state, from which there did not seem

to be any escape. This unfortunate period had caused most of the works to see that their position was better under the cobalt contracts which they had fought so hard against, even although they did not receive the principal advantage themselves, which went rather to the contractors because when they had open dealing and the times were uncertain the works which lacked capital depended altogether on foreign dealers. Moreover, the worst of the storm of war was past. It is true that in 1642 Schneeberg was sacked again by the Swedes, but on the whole more peaceful times were dawning, and moreover the cobalt mines had been producing better ore for some time. As the result of all these causes a gradual wish began to be expressed for a general contract and the establishment of color works in Saxony, a plan which, if successful, would probably give cobalt mining a sounder foundation than the sale of cobalt and oxide to foreign dealers. Some offers were made by different parties which were not accepted, as there was no guarantee that they would be able to carry out the contracts, and after some considerable discussion and negotiation the Prince summoned the principal officials of the mining office, the civic officials and whatever contractors were willing to bid, to meet together and lay their proposals before him, to see if they could make a contract by which the works could sell a fixed amount of good, medium and low-grade cobalt, the payment to be in cash, according to the assays of the ore. The small works, too, which could only mine a little cobalt, were to receive consideration, and moreover all the wages were to be paid in money, and not with color or cobalt. The sale of cobalt to Joachimsthal in Bohemia, was to be absolutely forbidden, and if they did not succeed in closing a contract the Prince was to receive a report as to how far they advanced, together with advice as to what should be done in the meantime. Before these officials had finished the task set them by the Prince an advance was made towards this goal from another quarter. In March, 1641, the Hamburg dealer, Hans Friese, made a private contract with six of the cobalt mines in Schneeberg. This agreement was filed in the mining office, and it contained express provision that the contract should be cancelled immediately the Prince succeeded in making a new one. The substance of it was as follows: Friese was to take from the works in question for three years 300 cwt. of cobalt, and was to pay them in cash immediately on delivery at the rate of two thalers and six grochen; the works could easily receive a part of their payment from Friese in goods and should the works mine more cobalt, this excess was to be offered to Friese first, and if he did not wish to take it they could sell in any way they liked. The cobalt should be pure and thoroughly cobbed out, without any hornstone, slate or pyrites. The first delivery was to be made at Easter, 1641, and then every six weeks following—smaller contracts were made by others with different mines. In the meantime the officials who had been commissioned by the Prince to make a contract had not been successful. This was due chiefly to the opposition of Hans Burkhardt, and therefore the mining office ordered that a temporary contract should be made, and for this temporary contract Hans Friese and Schnorr made a bid. Schnorr had, a short time before that, built a small color mill, and wished to work up the Schneeberg cobalt there, and he stated that he was willing to contract for a year on condition that during this time no blue color work should be built in Saxony. This contract was actually agreed on between these two and twenty-three of the works. In consequence of this further development of matters, Burkhardt gave up his former opposition and declared that he was willing to take part in the contract on condition that he should receive permission to erect a blue color works. The only opposition now was from Röhling, one of the contractors. He said that he had made a former contract with some of the Dutch, which he must adhere to, as the Dutch dealers had made him an advance, and if he cancelled the contract the money would have to be refunded. After his contract had elapsed he said he would be willing to join. The mining office, however, believed that it was not necessary to pay any attention to him, as his contract with the Dutch dealers was not recorded in the mining office, and was, therefore, not binding.

Local Customs Works, 1642

As a result of the conference, lasting several days, between the Prince and three of the contractors, namely, Friese, Schnorr and Burkhardt, an agreement was made which embraced all the Schneeberg works. It contained the following points: The agreement was between all the works which existed at Schneeberg and Neustadtlein and the contractors Hans Burkhardt, Hans Schnorr and Hans Friese, and made with each of the three individually and not jointly, for a period of six years. The three contractors above mentioned were to take from all the works, including the Prince's and their own, yearly a quantity of 2,400 hundredweight, and they were to pay according to samples which were to be kept in the mining office. The payment was to be in good money and at the rate of 3 thalers 18 groschen per hundredweight for No. 1 grade, 2 thalers 18 gros. for No. 2, and 2 thalers for No. 3. Cobalt ore which was better than these three grades or not equal to it, should be paid by the contractors according to the decision of the mining office. Each of the contractors was to take 800 hundredweight. The mines, on their part, were required under penalty of a heavy fine, to refrain from dealing in cobalt or oxide with any one else during the period of this contract. If one of the contractors should die, his heirs would be bound to carry on the contract until it expired. Friese had permission to export his cobalt, Burkhardt was allowed to build a color mill in Saxony, and Schnorr was to be also allowed to build one there and work up his cobalt. The agreement was finally confirmed by the Prince in 1642, and a decree was made against cobalt smuggling. In this decree every sale of cobalt in violation of the agreement, especially the sale into Bohemia, was to be punished by a fine of 500 florins, and if the fine could not be paid, corporal punishment would be substituted. The informant would receive one-half of the goods which were confiscated and the other half would be used for maintenance of the adit in Schneeberg. In accordance with the royal permission, Hans Burkhardt settled in Oberschlema, near Schneeberg, where he had picked out a site for his color mill. It is true there was some opposition from the town council of Schneeberg, which regarded this as an encroachment on their rights and jurisdiction, but on account of the concession granted by the Prince it was allowed to stand.

This new contract soon met with difficulties which endangered its permanence. At the very outset the works and the contractors were in dispute about the assessing of the cobalt according to the assays that were made. The contractors complained that the mining office assessed the samples which were better than No. 1 too high, and that they had introduced intermediate payments. The Prince decided that these intermediate valuations should not be used, and threatened with severe punishment those who did not obey. The samples which were better than No. 1 should be graded as No. 1, and those which were better than No. 2 but not quite as good as No. 1, should be graded as No. 1. If the differences were much greater, then they were to be paid according to the next lowest grade, and all ore which was not up to No. 3 grade need not be paid for at all by the contractors. The works were advised that by care they would almost always reach that grade. The Prince also warned them that they must keep the contract or they would not find any one to buy their cobalt.

A more serious danger threatened the industry in the following year. This was due to the death of Hans Friese. According to the terms of the contract his heirs were bound to carry it on, and as a matter of fact his widow tried this, but on account of lack of capital she was unable to carry out her obligations, and finally one of the principal creditors, Oehme of Leipzig, took over Friese's contract. A few years later, in 1647, after the expiry of the contract, which was made in 1641, all the success that had been achieved hitherto was jeopardized. Burkhardt refused most positively to make a new contract, even although the Prince threatened him if he persisted in his refusal to cancel his right to have blue color works, but Schnorr and Oehme stated that without Burkhardt's assistance they were not in a position to buy all the cobalt from all the mines, and they would therefore make provisional contracts with individual works. The works on their side, were not satisfied with that, and requested again for

permission to have open dealing, as they could not get any other contractors. The Prince against his will granted their request and allowed for a short time open dealing again, with the exception, however, that all trade with Bohemia was prohibited, because the Bohemian works, on account of the scarcity of their ore, were only able to exist with the help of the Saxon cobalt, which was of better quality. They then competed with Saxony in the color business. Not very long after this another individual named Schindler purchased a site in order to build blue color works, and in conjunction with the mining office and with the Prince's permission, he stated his willingness to enter into a contract. Finally an agreement was made for six years in 1649, according to which the four owners of the four Saxon color works, namely, Burkhardt, Oehme, the widow of Schnorr and Schindler were associated. The amount of cobalt which they agreed to take yearly was the same as before, namely, 2,400 hundredweight. The price remained the same as before, with the exception that one higher grade was introduced, was called No. 1 and was paid at the rate of 4 thaler 6 groschen per cwt. In all other points this agreement was the same as the previous one. Each one of the contractors was to take 600 hundredweight yearly. Both the works and contractors were forbidden most strictly to deal either in ore or oxide with Bohemia, and all the pearl ash, that is potassium carbonate, which was produced in Saxony was to be delivered to the four works in equal portions. This contract was ratified by the Prince in 1649.

Contract of 1649

By this means a fixed and certain contract was brought into existence again. In the place of frequently changing foreign contractors, four subjects of Saxony acted, each of whom was in possession of a color mill, and therefore had an interest in the preservation and continuation of the contract. The only one who had previously been opposed to this was Hans Burkhardt, because he was able without any contract to supply his works with his own cobalt ore. Thanks to the energetic efforts of the Prince and his officials Burkhardt finally yielded. It is true that some concessions were made to him in the new contract. It was theerfore of great importance that in the year 1651 the Crown Prince, Johann George, came into possession of the Oberschelma works and Burkhardt's cobalt mines. Burkhardt had died without heirs or relations, and in his will he had left to the Prince his four mines and all his works. The only reason that he gave for this was that the mining and the color business might remain as it was. By this means the Prince had more direct interest in the mining and color industry than he had before. At the same time a request came from some foreign company tbat they should receive permission for the erection of blue color works. The four contractors, of course, opposed this and requested that for a period of twelve years no new color works should be built in Saxony. They stated that the production would be overdone if further concessions were given, and the individual works would only ruin one another. They stated that there was an example of this in Bohemia where, after the erection of several mills, they had all been ruined except one, and moreover they stated that the pearl ash which was produced in Saxony was not sufficient for the four works which existed. They had to import two-thirds of their pearl ash from Bohemia.

The mining office agreed with this request of the contractors for the reasons given above, and advised granting a concession for twelve years on the condition that the contractors after the expiry of this contract should be willing to make a new one. It was certainly, under these circumstances, a good thing for the other proprietors of color works that the Prince himself was interested in one of the four. After some hesitation and urging on the part of the mining office, the Prince agreed that no new rights to build any color works should be given in Saxony. On their part the contractors were bound not only to keep the present contract strictly, but after its expiry to make a new one under more reasonable conditions "in order that the work which had so well begun should come down to posterity and flourish in vigor."

We see that by this means the foundations were laid for an industry which has lasted to the present time, for after the twelve years had elapsed, although there were

some attempts to build new works in Saxony, the four works that existed at this time were rooted so firmly that every attempt to encroach on their privileges was bound to fail.

CONCLUSION

The Period from 1653 to the Present Time

According to the agreement mentioned above there were four works, each of which was bound to take a certain quantity of ore yearly. One of these works was considered as a double one, and therefore the whole quantity was divided into fifths. The Oberschelma work was the double one. It will be noticed that one of the works belonged to the Prince and the other three were private. The three private works, which had been originally quite independent, in the course of time gradually came out of the control of single individuals into companies, which became more closely related to one another. As far back as 1659 the holders of the different works were agreed on the following points:—

1. All the works bind themselves to a fixed price for color below which no color may be sold. The common color cost 5 thalers per cwt. and the best color 10 thalers at the works. At Leipzig it was half a thaler per cwt. higher, and increased with the distance from the works.
2. None of the works during the period of the contract was to make more than 24 cwt. of color weekly.
3. Each of the works had to brand its casks of color with a certain brand in order that they could distinguish their domestic color from the foreign or Bohemian.

Later on, in 1845, the three private works were amalgamated into one and concentrated at Niederpfannenstiel. The works belonging to the State at Oberschlema remained as it was. Both these combinations are in union and form the so-called blue color trust. This owns all the Schneeberg mines, as well as the mine and works at Modum in Norway. Between the two works the old arrangement with regard to the disposition of the cobalt and the sale of cobalt still exists, viz., two-fifths and three-fifths. In all matters concerning the cobalt business they act in concert and exchange experiences, and experiments are undertaken at the common expense.

Leaving Bruchmueller's work and turning to the annual official reports it appears that the two works employed last year 225 men, including office staff, and that the product amounted to about 674 tons in weight and about $836,000 in value. (Jahrbuch fuer Berg und Huettenwesen).

Present State of Mining in the District of Schneeberg, Saxony

The chief characteristics of the vein systems are given on preceding pages.

Taking the only mines which have any production at all worth mentioning, and looking at the reports of the last ten years or so, it is evident that the character of the vein filling has changed since the early days. Bismuth now occupies an important position, as, wherever the contents of ore are given the precentage of bismuth stands high. Quotations from the Annual Reports show this. (See Jahrbuch fuer Berg und Huettenwesen in Koenigreich Sachsen). Silver is quite insignificant in amount, less than two per cent. of the value being credited to this metal. Thus in the report of 1893 (later reports give the value of silver, cobalt, nickel and bismuth together) the amount assigned to silver, etc., reduced to our currency, is as follows:

Silver	$2,700 00
Cobalt, nickel and bismuth	157,335 00
Uranium	1,666 00
Quartz, specimens and tailings	1,080 00
Total	$162,781 00

In the report of 1905:

Silver, cobalt, nickel and bismuth	$148,581 00
Quartz, specimens, etc.	1,855 00
Total	$150,436 00

The value per ton was about $570.

The result of all the development work being carried on now, consisting of drilling, drifts, crosscuts, rises, and sinking,—in short, trying in every way to open up veins known to be productive formerly or discover new ones,—is that here and there a rather small body of good pay ore will be found. Evidently the early productive period is long past. Occasionally they encounter difficulties due to striking old excavations, with accumulations of water or to the caving in of old works. Most of the work appears to be carried on at a depth of less than 1,000 feet.

Below are given translations of extracts from the Annual Reports, extending back about ten years. The reports are all on one mine, or rather group of mines, which was referred to above as being the only one of any importance. It is called Vereinigt Kobalt feld. About half a dozen veins are mentioned throughout the reports. Some of these were exploited in the early period of mining in that district.

In the report of 1893:

"On the Junge Zeche Spat, (one of the most productive veins in recent times) in a drift of about 280 feet in length for a distance of 83 feet, solid bismuth ore sometimes ten inches wide with 30 to 50 per cent. bismuth was found, also concentrating ore along a distance of 183 feet. The minerals were bismite, native bismuth, smaltite, chloanthite, native silver, ruby silver, argentite, galena in vugs with mimetite (arsenical lead chloride), eulytite (silica of bismuth), cobalt bloom, chalcopyrite, chalcocite, and cinnabar."

"The most important strike in the whole district was made on a vein which was 16 to 24 inches wide and carried very rich bismuth cobbing ore for 52 feet in length and then concentrating ore for 296 feet."

"A body of ore 45 feet long with a considerable amount of roselite (lime cobalt arsenate) was found."

In report of 1900:

"Exploration of the most important vein, Junge Zeche, was undertaken. The productive portion of the vein ended at a depth of about 830 feet from the surface. (This was the case with most of the veins.)"

Report of 1901:

"In a crosscut 770 feet from the shaft a strike of rich bismuth ore, sometimes with disseminated ruby silver, also cobalt bismuth ore associated with pitchblende (uranium ore) and niccolite was made."

"A strike was made in the granite* over 230 feet from the slate contact, of rather a large bunch of bismite, with native bismuth. Near the contact the bismuth ore was richer and was ten inches wide."

"Another discovery was made in a drusy quartz vein over three feet wide where solid cobalt nickel ore was found on the hanging, and bismuth on the footwall."

Report of 1902:

"Junctions of veins proved especially rich in native bismuth. Along with bunches of bismuth ores were associated cobalt-nickel ores and uranium."

Report of 1903:

"From an area of vein surface of about 270 square yards about fifteen tons containing 19 per cent. bismuth, 4.3 per cent. cobalt and 2 per cent. nickel was taken" (the width of the vein not given in this case). "Another ore body containing 20.6 per cent. bismuth and 3.6 per cent. cobalt was found. The contact again proved favorable."

"In a vein 44 inches wide bunches of bismuth ore occurred."

*The granite is younger than the schists in which the veins are found, and underlies them.

Other strikes mentioned contained 7.3 per cent. bismuth, 5.6 per cent. cobalt; another 33.9 per cent. bismuth, 2.6 per cent. cobalt, and 1.3 per cent. nickel.

1904 report:

"Strike was made 24.2 per cent. bismuth, and 4.1 per cent. cobalt."

"A stringer was found containing pucherite (vanadanate of bismuth) showing throughout all the ore."

Report of 1905:

"Strike of ore was made 25 feet long (width not given) with 21.4 per cent. bismuth and 2 per cent. cobalt. Another strike of bismuth ore of shipping quality 28 feet in length and about 35 feet of concentrating ore. The vein was about 20 inches wide, consisting of quartz, hornstone with bands of bismuth ore and contained 28.6 per cent. bismuth as taken out."

These rare minerals and their associations are mentioned in order that those interested in the Temiskaming district may look up the descriptions of the various minerals and be on the watch for them.

It is remarkable that of all the metal mines, some hundreds in number, which once produced ore in Saxony, and which played such an important part industrially, and also technically, in the development of the art of mining, concentration and smelting, the cobalt-bismuth-silver mines of to-day are the only ones which are not operated at a loss.

REPORT OF 1911

According to this report the richest ore taken out was from a vein of which approximately 800 square metres vein surface were mined. The return for a square metre vein surface was about 22 lbs. metal, of which over 90 per cent. was bismuth. Reduced to our systems the yield was $28 per square yard vein surface.

In another mine (Marx Semmler Stolln) radio-active water was found in following a little cross vein from one of the old workings. In one place water coming at the rate of about two gallons per minute was strongly radio-active. In another place the quantity of water was three times as great as above mentioned with a radio-activity slightly less.

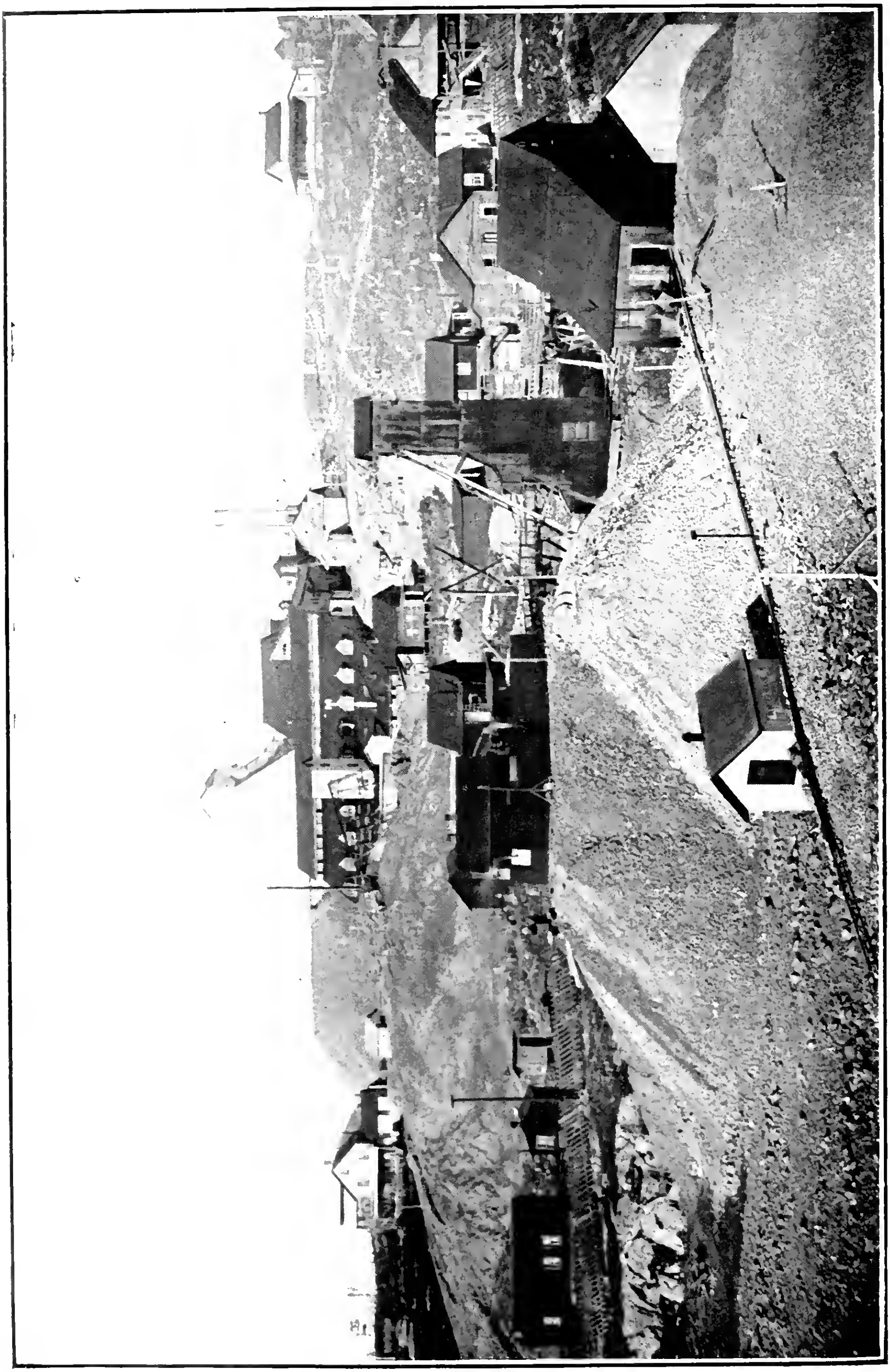


Fig. 109.—Coniagas concentrator and shaft house, with one of the Nipissing shaft houses in the foreground.

APPENDIX IV

MINING AND CONCENTRATING METHODS AT COBALT

By E. T. Corkill

Most important developments have taken place in the Cobalt silver mines since the third edition of this Report was published. The production of silver from these mines has raised Ontario to the rank of the world's third largest producer, surpassed only by Mexico and the United States.

Owing to the number of mining companies now concentrating their low-grade ore, it is misleading to compare the tonnage shipped with the shipments of former years. The only fair comparison is the number of ounces shipped. These shipments are given on another page of this Report.

The statistics show that up to December 31st, 1912, 44 mining companies in the Cobalt camp have shipped ore. Some of these companies ship from several mines, so that the total number of mines that have produced ore is in excess of this number. Of these 44 companies, 21 have paid dividends. This includes two mines, privately owned, the amount of whose dividends has not been made public. There are at present fourteen companies in the camp paying regular dividends, and one privately owned mine, so that the decrease in dividend payers has not been very large. The increase in dividends paid by certain companies more than makes up for the suspension of dividends by others.

Mining Methods

With the developments of the mines, a change has taken place in the mining methods. In the early days of the camp, most of the ore was mined from narrow open cuts. This was a cheap method for extracting the upper part of the high-grade silver veins, but, as the veins were followed to greater depths, more systematic methods had to be adopted, both for the extraction of the ore and for thorough prospecting underground. To accomplish this, small shafts, generally 5 ft. by 8 ft. inside timbers, divided into two compartments, one for hoistway and one for ladderway, are sunk on the veins. Stations are cut at intervals of from 75 to 100 ft., and drifts run on the veins from these stations. The shafts are practically all vertical, as are the veins. Most of the stopes are carried from 5 to 6 ft. in width, and overhand stoping is adopted practically all over the camp. When the veins are fairly uniform in values, timbers are put in over the drift and the rock and ore broken on these. Chutes are put in every 30 to 40 ft., and the surplus rock is drawn from these as the ground is broken. The rest of the broken rock is left in the stope, until it has been carried to the next level. In this way, the men are within a few feet of the roof at all times, ensuring safety, and are always within reach of the work without staging. In other mines, where the values of the ore change rapidly, and it is advisable to keep the waste separate from mill rock, all the rock is drawn from the stope as broken. Stulls heavily lagged are put in the stope about every 12 feet, and the men work from these. The walls of the stopes are as a rule quite solid, and can be made safe, if care is taken in scaling. As an evidence of this, the records show only one man killed to January 1st, 1913, from falling rock while working in the stopes of the mines at Cobalt. Owing to the narrowness of the veins, and the fact that sometimes the veins at the surface are either heavily covered by overburden, or only show cracks, it is necessary to do a great deal of exploratory drifting and cross cutting. The total amount of sinking, raising, drifting and cross-cutting done by the forty-four producing mining companies, up to January 1st, 1913, is in excess of 50 miles of work. More than 50 per cent. of this represents exploratory work. But little hand drilling is done at Cobalt. The companies use for development and exploratory work the machine drill with 3⅛ to 3¼-inch cylinders. The rock is hard to drill, but breaks well when drilled. The average number of 5-ft. holes drilled to break a heading 7 ft. by 6 ft. in a drift or cross-cut is 10, which make, when blasted, about 4 feet of progress. The hammer drill is used to some extent in stoping, but it has not been largely adopted by the companies, though it is used almost altogether for raising.

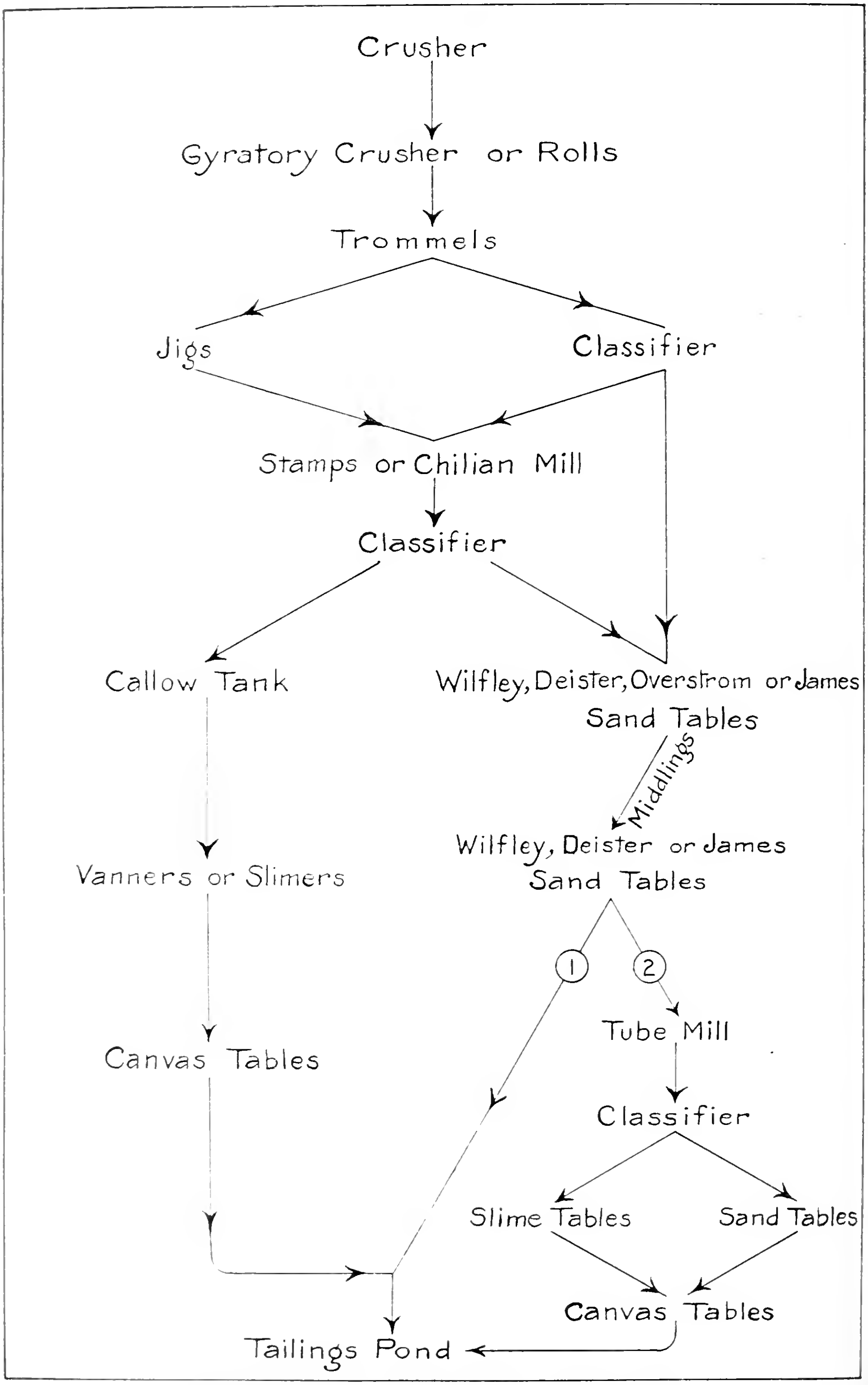


Fig. 110.—General flow sheet, Cobalt concentrators.

Power Development

The summer of 1910 saw the introduction of hydro-electric and compressed-air power into the camp. The Cobalt Power Company and the British Canadian Power Company supply electric power and the Cobalt Hydraulic Power Company compressed air. The British Canadian Power Company also supplies compressed air generated at Cobalt and at Brady lake by electrically driven compressors. These companies were amalgamated in 1912 under the name of the Northern Canada Power Company. Electric power is delivered at the mines for $50 per horse power per year, and the compressed air at 24c. and 25c. per 1,000 cubic feet at 100 pounds pressure. These prices represent a saving to the mining companies of over 50 per cent. of the cost of generating power by the use of coal, and have enabled the larger companies to increase their mining operations without increasing their power plants. This power reduces the cost in opening up new work, the construction of plants being obviated.

Concentration

One of the greatest advances in the economic treating of the cobalt-silver ores is in concentration. On account of the narrowness of the veins and the stringers of ore branching off from the main veins, it has been found that, no matter how carefully this ore is sorted, a considerable amount of silver is left in the rock. This averages from 10 ounces per ton up to 50 or 75 ounces. To recover this, the present system of concentration has been adopted. In 1908, when the third edition of this Report was published, there were five concentrating mills in Cobalt having the following capacities:—

	Tons per day.
Buffalo	60
Coniagas	50
Cobalt Central	60
Northern Customs	50
Ore Reduction Co.	40
Total	260

On January 1st, 1913, the following companies had concentrating mills in operation and in course of construction having the respective daily capacity:—

Mill.	Capacity per day	No. of stamps.	Remarks.
1 Beaver	90 tons	Crushing by rolls	Increasing capacity in 1913.
2 Buffalo	145 "	" "	
3 Cobalt Central	75 "	" "	
4 Cobalt Lake	75 "	20	Doubling capacity in 1913.
5 Colonial	25 "	10	
6 Coniagas	180 "	60	
7 Dominion Reduction	120 "	40	Customs mill.
8 Hudson Bay	60 "	20	
9 King Edward	30 "	10	
10 McKinley-Darragh–Savage	165 "	30	Adding 20 stamps.
11 Nipissing	200 "	40	
12 Nipissing Reduction	50 "	Crushing by rolls	Customs mill.
13 Northern Customs	350 "	120	" "
14 O'Brien	100 "	30	
15 Silver Cliff	75 "	Crushing by rolls	
16 Temiskaming	125 "	40	
17 Trethewey	100 "	30	
Outlying camps.			
18 Casey-Cobalt	30 "	10	Doubling capacity in 1913.
19 Wettlaufer	30 "	Crushing by rolls	
20 Miller Lake-O'Brien-(Millerett)	30 "	10	Recently purchased from Millerett by Miller Lake-O'Brien
Totals	2,055 tons	470 stamps	

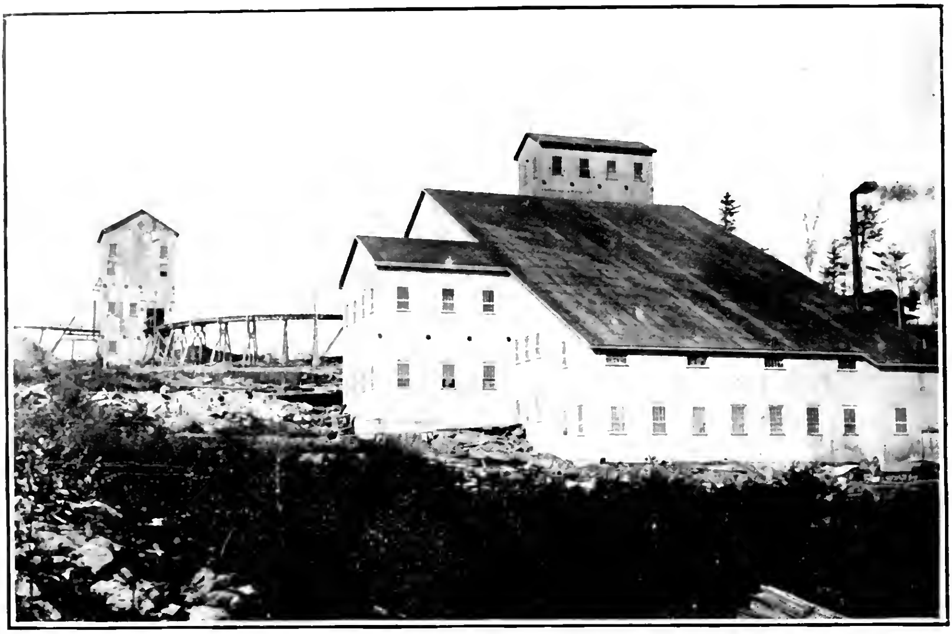


Fig. 111.—O'Brien concentrator, Cobalt.

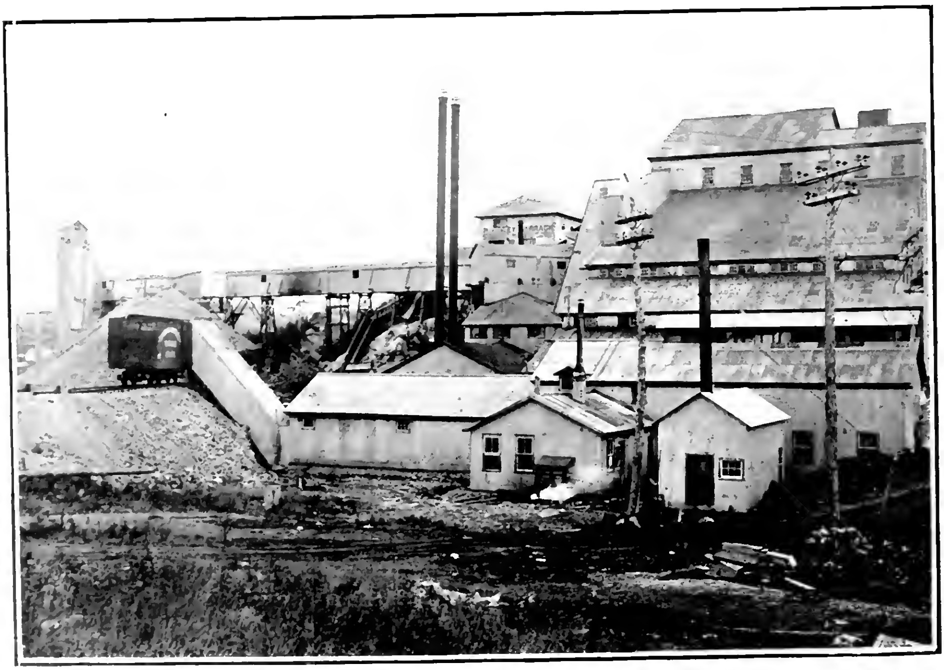


Fig. 112.—McKinley-Darragh mill and shaft house, Cobalt.

Computing this concentration on a basis of 10 tons of rock milled, yielding 1 ton of concentrates, the mills will produce 51.3 tons of concentrates per 24 hours, or in 310 working days in the year 15,903 tons of concentrates. At an average value of 900 ounces per ton of concentrates, the total amount of silver produced by the mills would be 14,312,700 ounces. However, it must be borne in mind that, owing to breakdowns, etc., the mills very seldom operate to their full capacity. Three of the mills mentioned above use water concentration and cyanidation of the tailings. The other mills use water concentration solely. A number of other mines have adopted concentration of their coarser material. All the producers of ore do a certain amount of hand picking, either from bumping tables or travelling belts, but at the Cobalt Provincial, Crown Reserve, Kerr Lake, La Rose and Savage mines, jigs have been installed to make a better saving of their finer material. The average grade of rock sent to the mill is about 25 ounces per ton, though it sometimes runs as low as 10 ounces and as high as 75 to 100 ounces. The average recovery in the mills is about 80 per cent. of the silver values. Thus in a 25-ounce ore, the recovery is 20 ounces, and the loss in the tailings 5 ounces. The average milling cost is approximately $3.00 per ton of rock treated, thus the profit on 25-ounce ore would be as follows:—

One ton ore	25	ounces
Less 20 per cent. milling loss	5	"
	20	"
Smelters pay for 90 per cent., or for 18 ounces silver at 60c. an ounce	$10 80	per ton
Less milling cost	3 00	"
Profit	$7 80	"

Practically the same principle is adopted in all the mills, the only difference being in the details of the treatment. The majority of the mills use jaw crushers and stamps for crushing, and reduce the ore to 15 or 20 mesh. Some of the mills use tube mills for fine grinding.

The flow sheet, Fig. 110, illustrates the general method adopted in the mills in the camp.

In some of the mills the tailings from the sand tables, as outlined in (2) on flow sheet, are reground in tube mills, classified and then treated on slime and sand tables, and then over canvas tables. A great variety of tables are used at the various mills. Among the tables used are the Wilfley, Deister, James, Frue Vanner, Overstrom and Traylor. The weight of stamp used throughout the camp is 1,250 pounds, and crushing in the stamps to from 16 to 20-mesh, if there is no re-grinding.

Smelting

In the early days of the camp there was little competition among the smelting companies in buying cobalt-silver ores. On January 1st, 1913, there were nine companies buying these ores. Three of these smelting companies have their plants located in Ontario. They are as follows:—

1. Coniagas Reduction Company, Thorold.
2. Deloro Mining & Reduction Company, Deloro.
3. Canada Refining & Smelting Company, Orillia

The three companies mentioned treated more than 50 per cent. of the total number of ounces of silver shipped from the camp in 1910.

The other companies buying cobalt-silver ores are:

1. American Smelting & Refining Company, New York, U.S.A.
2. Balbach Smelting & Refining Company, Newark, N.J.

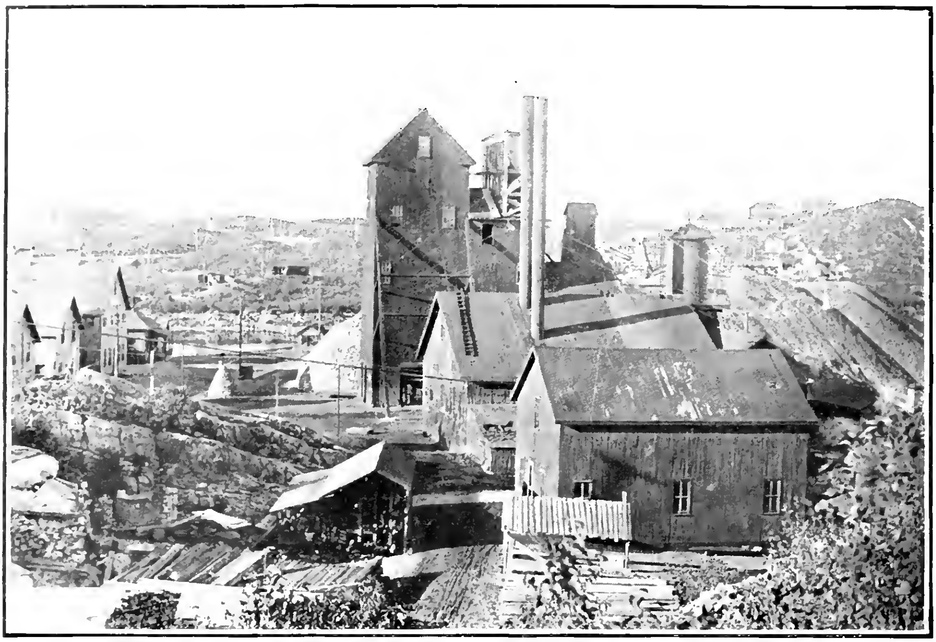


Fig. 113.—Crown Reserve Mine, Cobalt.

Fig. 114.—La Rose main vein, 1905.

3. Pennsylvania Smelting Company, Pittsburg, Pa.
4. United States Metals Refining Company, New York.
5. Beer, Sondheimer & Company, Frankfort-on-Main, Germany.
6. Government of Saxony, Saxony, Germany.

Considerable silver is also refined at Cobalt itself. An interesting account of the refinery at the Nipissing mine has been recently published.*

Accidents and Labour

There have been, up to December 31st, 1912, in both the producing and non-producing mines of Cobalt and vicinity, 114 men killed above and below ground. The value of the total production of Cobalt, up to the above date, is about $81,000,000. To produce this amount of wealth, it cost the lives of 114 men. This means that an average of one man was killed to produce ore to the value of approximately $710,000. In the gold mines of the Transvaal, the average for five years shows that one man was killed in producing ore to the value of approximately $200,000. In the coal mines of the United States, statistics show that for an average of the last five years, there has been one man killed in producing 174,390 tons of coal.

When the Cobalt silver mines were discovered and mining work begun, there was a scarcity of skilled miners, and it was necessary to take on unskilled workmen and train them. In addition, on account of the veins being narrow, in some cases a mere crack developing ore within a few feet, numberless shafts were sunk all over the camp. This prospect work of shaft sinking is more hazardous than after a mine is developed and work well organized. In Europe, most of the metal mines have been worked for years and employ many more men, on the average, than do the mines and prospects of Canada. Moreover, European miners can be said to have inherited their vocation, in most cases their ancestors having been miners for generations. In Canada, we have little of that class of labour. As a result, the accident rate has been proportionately high. The labour is very cosmopolitan in character, but the majority of the men are Canadians. There are also men from the British Isles, Americans, Finlanders, Swedes, Polanders, Hungarians and Italians employed. The last three nationalities are used largely as surface labourers.

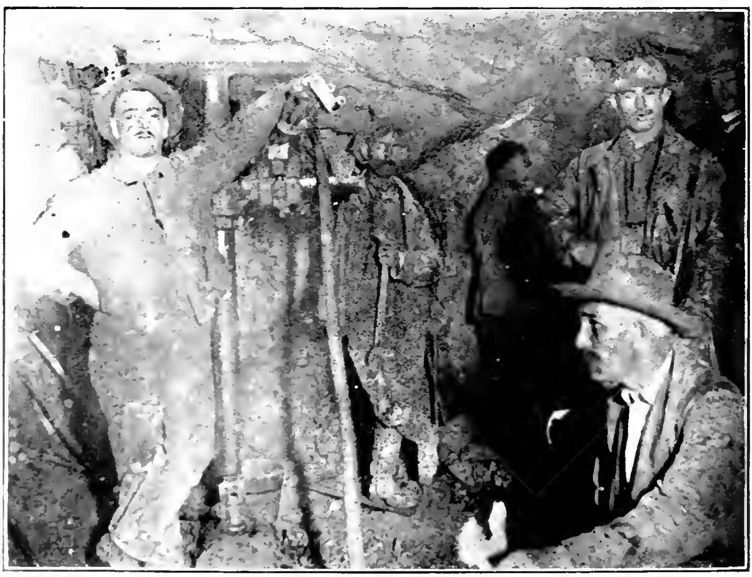
The following table shows the ruling rates of pay for employees at the Cobalt mines: —

Classification.	Average pay per 9-hour shift.
Shift Bosses	$4.00 to $5.00
Timbermen	3.25
Pumpmen	3.25
Machine drillers	3.25
Machine helpers	2.75
Machine drillers in wet shafts	3.50
Machine helpers in wet shafts	3.50
Hand drillers	2.75
Cage tenders	2.50
Trammers	2.50
Pipe fitters	2.75
Engineers	.30 an hour
Firemen	.25 "
Deck tenders	2.50
Surface labourers	2.25
Blacksmith	3.25 to $4.00
Blacksmith helper	2.50
Ore sorter	2.25
Carpenter	3.25

A deduction of 60c. per day is made for board, and $1.00 per month for hospital and doctor's fees.

*R. B. Watson, "Nipissing High Grade Mill, Cobalt." Eng. and Min. Jour. Dec. 7th, 1912.

Fig. 115.—Trethewey vein and discovery post, May, 1904.



[illegible] w at La Rose mine, 1905. From a photograph by Mr. A. de Romeu

Explosives

The Mining Act of Ontario only regulates the storage and use of explosives at the mines. There is no regulation regarding the manufacture or statistics to show the amount used.

The manufacture of explosives is a matter of trade and commerce, and as long as the explosive remains in the form of a commodity which is open to purchase and sale, it is subject to the supervision and jurisdiction of the Dominion Government. As soon as it is brought for use on the mining property, regulations passed by the Provincial Legislature govern. It has been felt for some time that the Dominion Government should bring in legislation respecting the manufacture and sale of explosives in Canada, in view of the numerous accidents resulting from explosives. The Dominion Government have had this matter under consideration for three years, but nothing has yet been done. The principal explosives used are dynamite, gelignite and cheddite. The companies supplying the bulk of the explosives are the Canadian Explosives Company, with works at Beloil, Quebec; the Curtiss & Harvey (Canada), Limited, with works at Dragon Station, Quebec; and the Energite Explosives Company, with works at Haileybury, Ontario.

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